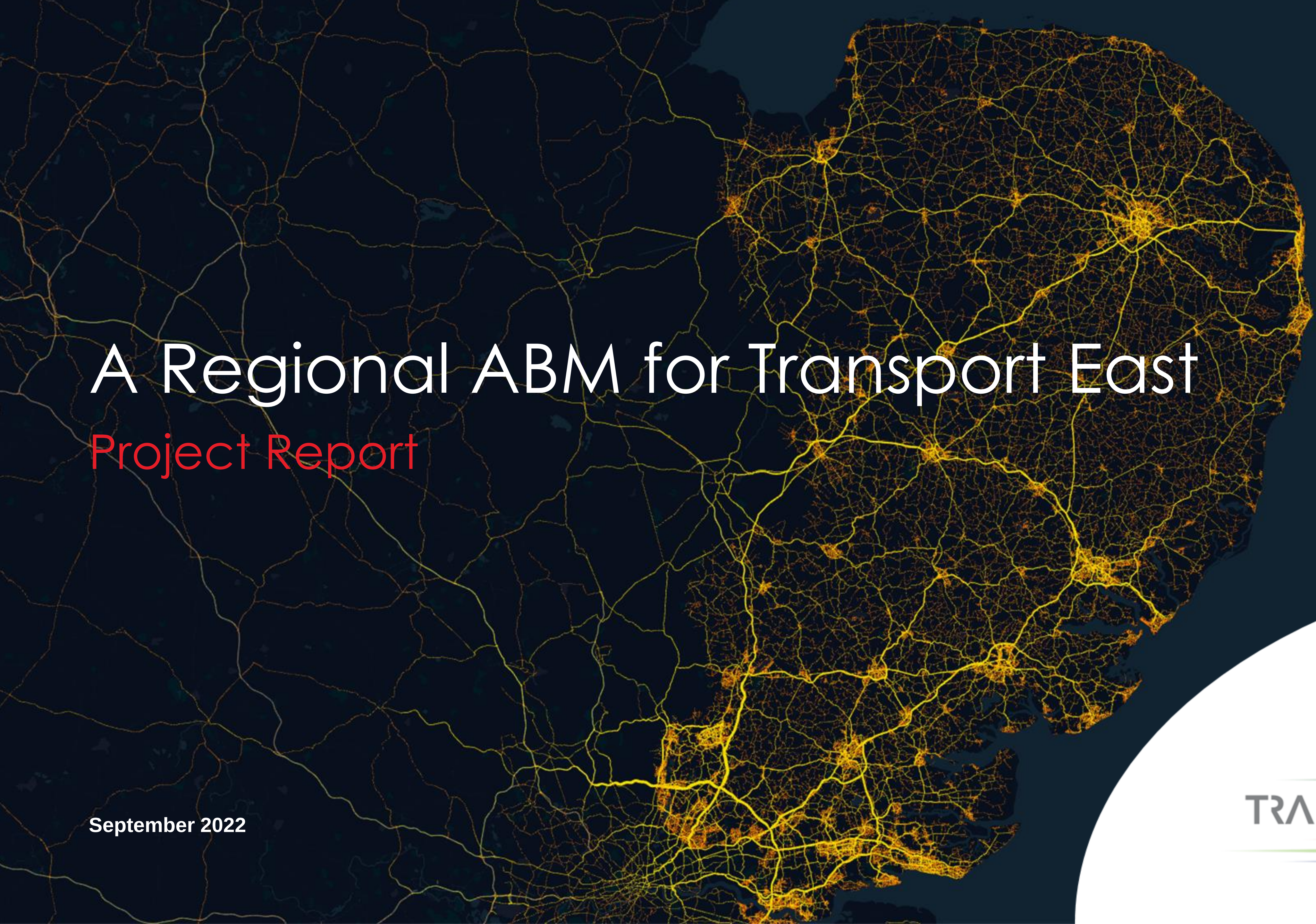

A Regional ABM for Transport East

Project Report

September 2022

ARUP

TRANSPORT EAST

Introduction

- Authors and QA
- About this document
- Glossary and terminology

Document quality control

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About this document

Overview of this report

This document

This document is the key (non-technical) deliverable for the first phase of the Transport East Agent Based Model (ABM) development.

Purpose

To give an overview of the development of the Transport East ABM, and focus on the analysis and insight generated from this first iteration of the model.

Contents

Glossary and terminology

ABM is an acronym that can have many meanings

The acronym ABM can have multiple meanings, we seek to be consistent throughout this document and offer the following definitions

Agent Based Models (ABM) simulate the actions and interactions of individual autonomous agents within an environment (such as people within a city). They use rules to define individual agent responses to their environment (including other agents). The interaction of these agents in the environment produces complex emergent behaviour at a systems level.

Activity Based Models (ABM or AcBM) model people's demand for travel as chains of activities. Choices range from the long-term, such as where to live and work, to the medium term, such as if to stop by the shop on the way home, to short-term, such as what time to leave the house. In this model we sample activity plans from diaries and assign these to agents.

Agent and Activity Based Models (A2BM, AABM, ABM) are agent based models where each agent has a set of activities that they are trying to fulfil. The Transport East ABM is an agent and activity based model implemented in MATSim supported by Arup developed tooling.

In this document the terms 'ABM' and 'model' are used to refer to the specific model we have built for Transport East. We may use the term 'simulation' to refer to the simulation component of the overall model (see page 7).

Further details on modelling terminology can be found on the City Modelling Lab Blog.

Project context and approach

- Project context and objectives
- Stakeholder engagement
- Engagement findings
  - Current focus
  - Future development

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Simulating travel behaviour

How does an agent based model work?

The Transport East ABM is a model built by Arup on the open source simulation framework MATSim (matsim.org).

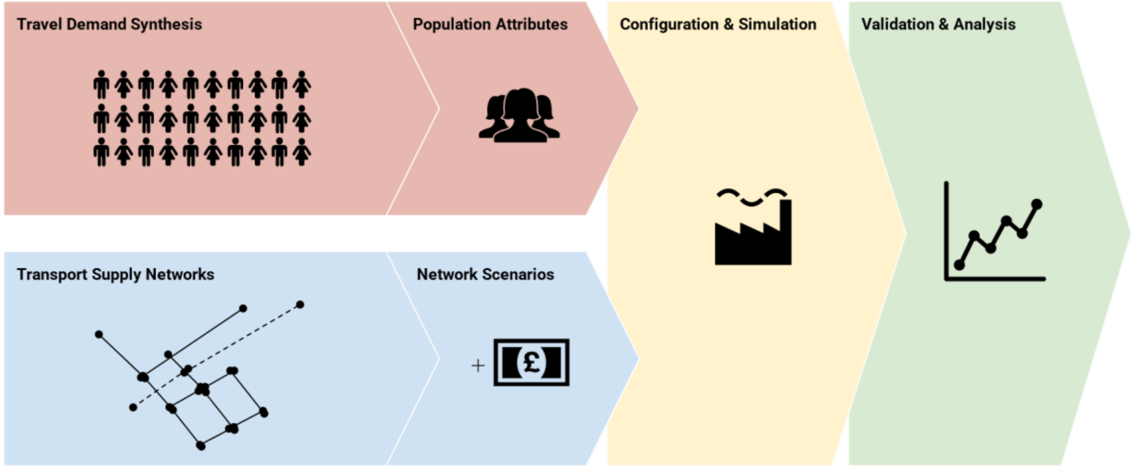
The simulation brings together a population of synthetic agents that is representative of the people living in the Transport East region. These agents are given activity plans that are designed to be representative of real people's days, comprising of the activities that they undertake with locations for those activities.

These agents are then simulated through a full 24 hour day as they try to fulfil their plans. They choose when to travel, which mode to use, and the route they take. Within our simulation, agents can choose between driving a private car, using a taxi, using public transport, or using active modes (walking and cycling).

At the end of each day, the agents work out how well they were able to succeed in fulfilling their plans, and calculate an overall utility for the day. They then can 'innovate' and try something different. We simulate the same day over and over so the agents can learn what works and doesn't work for them, while every other agent is trying to do the same thing.

At the end of hundreds of iterations of this day, agents have optimised their transport choices and optimised their utility. This gives us a set of emergent behaviour across all agents, showing how busy different modes of transport are, what choices agents are making and why, and how outcomes vary across different segments of the agent population.

This gives us unprecedented granularity with which to generate insights to support decision makers shape future policy.



Structure of an Agent Based Model

Project context

What motivated the development of the ABM?

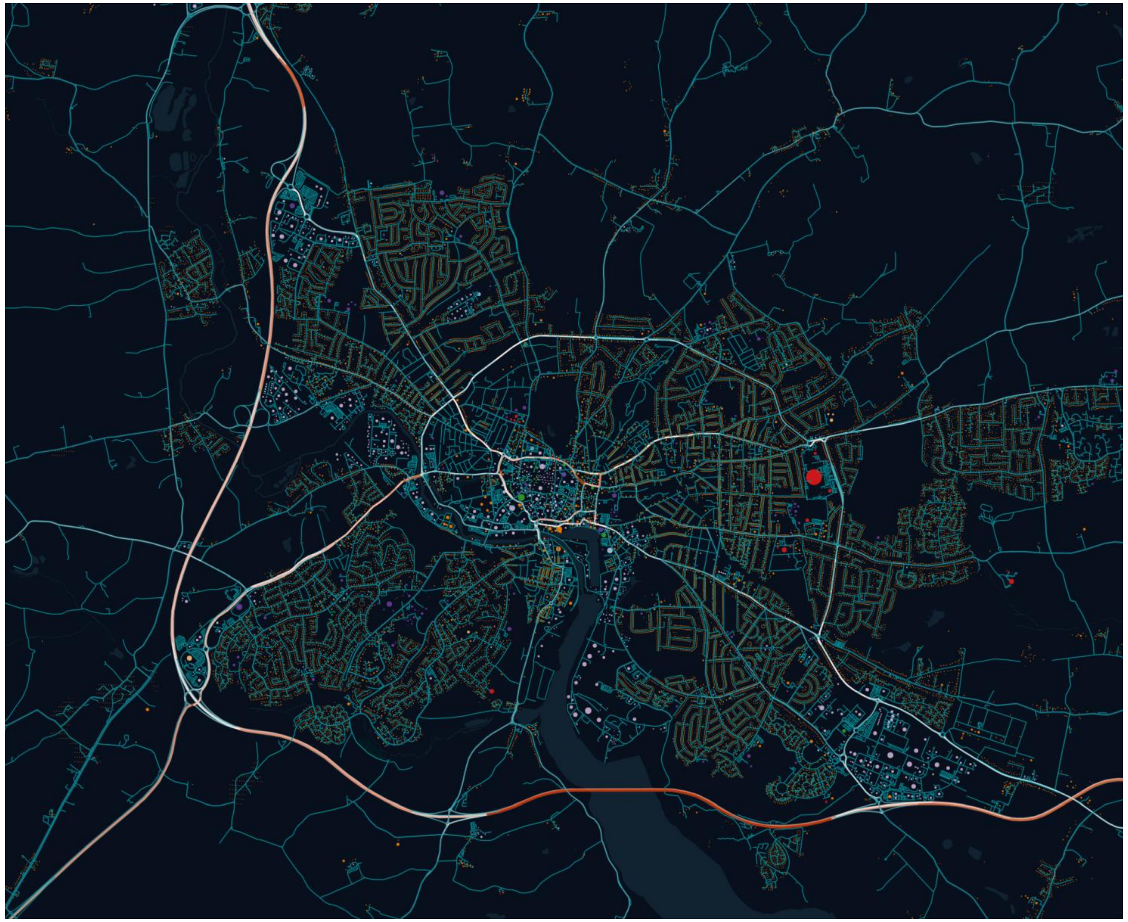
In 2021, Suffolk County Council funded the development of an Agent Based Model of the county.

The model was built and used over a period of six months, including specific analysis to input into the Suffolk Bus Service Improvement Plan (BSIP).

The flexibility and detail provided by this modelling approach is suitable for modelling a wide range of changes and policy interventions

In 2022, Transport East commissioned a larger scale model of their entire region to enable both regional and local questions to be assessed consistently by authorities and districts in the region.

The potential for an ABM to support Transport East's priorities of transport decarbonisation, connecting growing places, and energising communities is really exciting, and can support regional value add across all of Transport East's constituent authorities.



Ipswich Network Visualisation: Suffolk County ABM

Project objectives

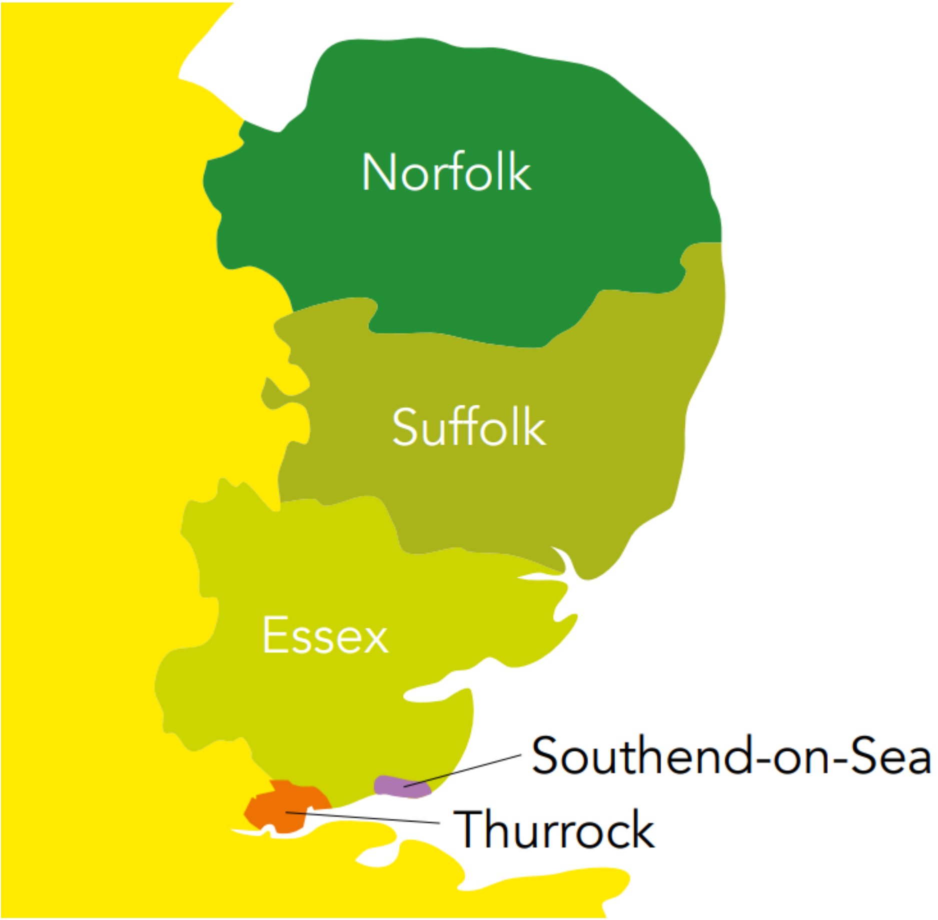
What did we set out to achieve?

We wanted to replicate the level of model maturity that was built for Suffolk across the whole of the Transport East region.

Objective: Build an agent based model of the Transport East region to support policy assessment and generate insight to support strategic decision making. This included:

- Build a baseline model of 2019
- Build a 2040 future year model
- Assess a range of high level scenarios, focusing on carbon assessment as an output
- Understand wider use cases for a range of stakeholders
- Ensure that model outputs are accessible and shareable more widely

Agile working: The core client team being integrated into the project. We worked in an agile way refining our understanding of what was of most value to Transport East and wider stakeholders. This meant that the methodology that we used and the scenarios that were being tested were able to change through the course of the project.



Transport East Region and Authorities. Source: Transport East Business Plan 2021/2022

Stakeholder engagement

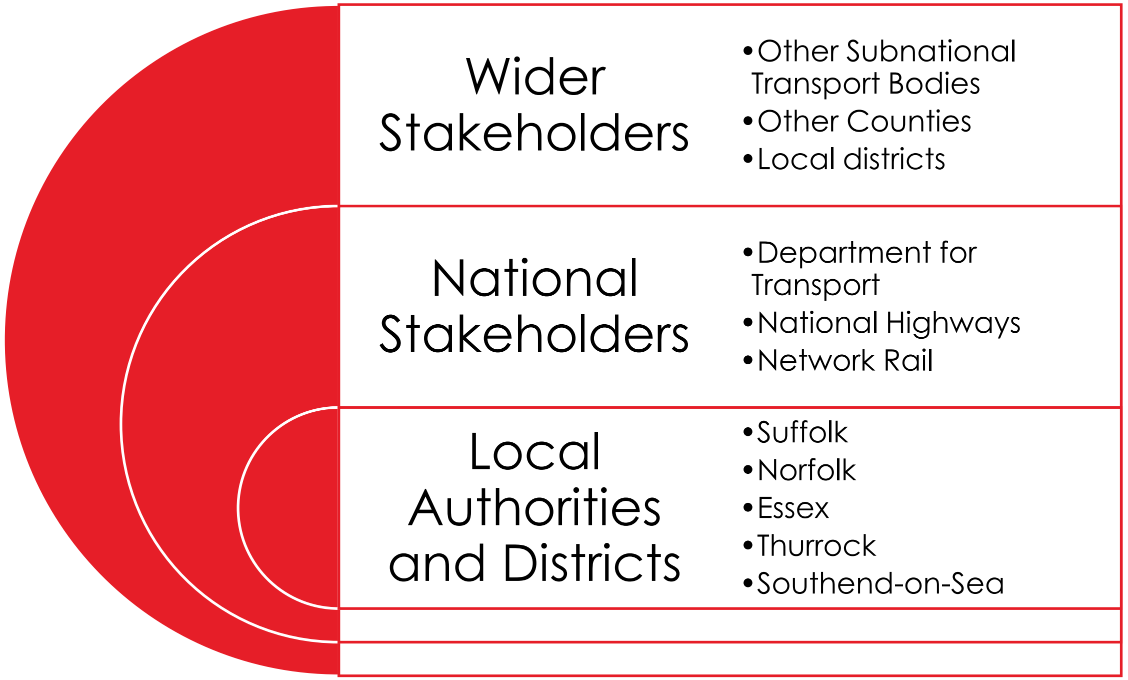
Who did we engage and why?

For this model to add value to decision making, we need to acknowledge that there are a number of key challenges and opportunities we need to address:

1. Transport East as an organisation is trying to bring a regional perspective and support its membership
2. This modelling approach is new and innovative, and is complementary to existing approaches
3. There is a diverse range of needs for use of the model across different authority levels, (Transport East, Local Authorities, and district councils)

It was therefore a core part of the project to engage with a wide group of stakeholders to ensure that each of the Transport East Local Authorities, national stakeholders, and as wide an audience as possible were appraised of progress and consulted as part of the project.

Details of how we engaged are on the next page, and feedback from stakeholders will be key in how the model is developed and used going forward.



Stakeholder groups engaged during the project

Stakeholder engagement

The Use Case Workshop

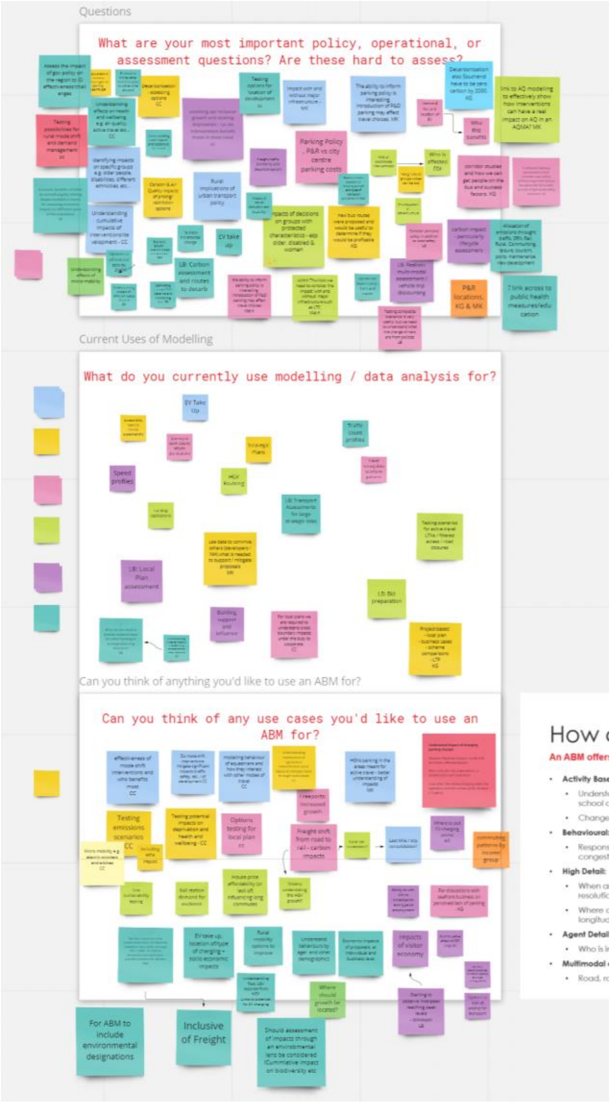
The use case workshop was run early in the project with Local Authority and Transport East stakeholders. The objective was to understand the possible uses of the ABM across different groups ranging from regional to district level policy questions.

This began by trying to understand the questions that each attendee needed to address, and whether the tools that they had were able to give them what they needed to support their decisions.

We then ran through the potential uses for the ABM and explored specific use cases and how the model could be used to address the key questions.

From this session we pulled out some core requirements – not just for use cases, but for the types of outputs, ability to disaggregate, and look at different segmentations of the output. High priority for stakeholders was an understanding of which agent groups were most impacted by changes, and the overall emissions impacts.

The overall outputs from the full range of stakeholder engagement are shown on subsequent pages.



Miro board from the Use Case Workshop

Stakeholder engagement

The Scenario Workshop

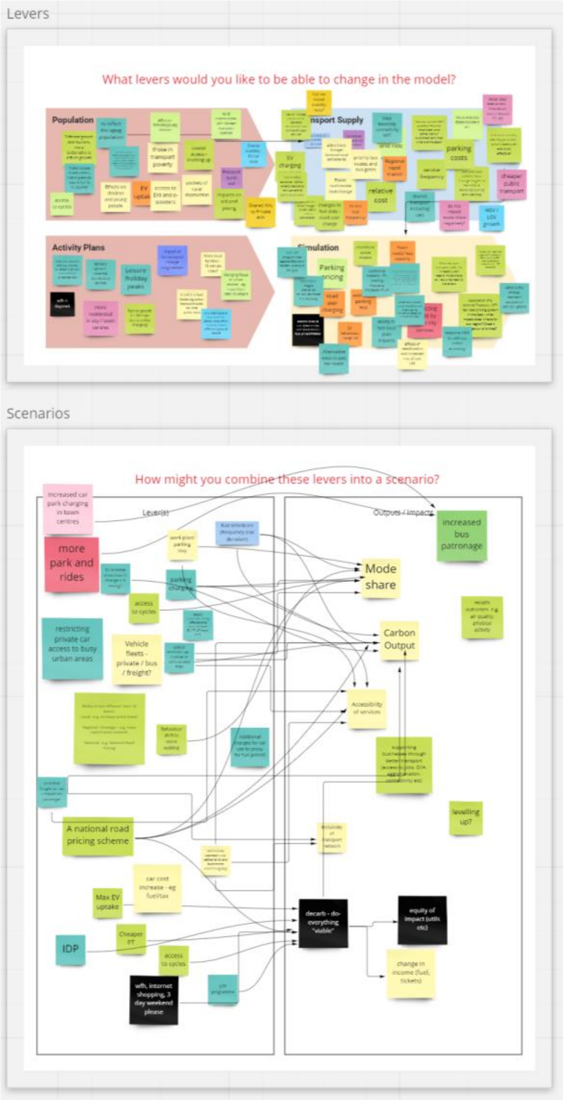
The scenario workshop was undertaken as we finalised the scenarios that were to be tested with the model. It built on the outputs of the Use Case Workshop, focusing down to specific scenarios that the individual authorities wanted to run as part of the project.

We split up the exploration of scenario levers into the different components of the model – with the majority of the desired levers being about supply side scenarios. This is understandable as the supply side is the area where stakeholders have more control over aspects of the supply.

This is an interesting observation, since focusing on the levers which each organisation has control over is most useful for their decision making on a day-to-day basis, some demand factors are likely to be very significant in minimising the carbon output of the region's transport system.

An overview of the scenarios that were modelled are described later in this report. The detail of the scenarios is shown in the appendix.

The overall outputs from the full range of stakeholder engagement are shown on subsequent pages.



Miro board from the Scenario Workshop

Engagement findings – Current focus

Our engagement and workshops have highlighted a number of areas for focus for this phase

The disaggregate detail of the model is a differentiator

The ability to look at the detail of the simulation is very important. This includes the temporal, spatial, and agent levels of detail. The flexibility of the modelling is very valuable for future assessment of scenarios.

Multi-modality is very important when understanding outcomes

Understanding the full range of modes (especially sustainable modes) and their interactions is important for balancing across the region. Decarbonisation won't be achieved without action on all modes.

Decarbonisation is part of a wider sustainability agenda

Moving to Net Zero transport is one of Transport East's strategic priorities. However, things like air quality and other benefits from sustainable travel (e.g. health improvements) need to be quantifiable.

Freight is one of the factors that is most important

With two potential Freeports, and significant cross region freight movements, the Transport East region needs to understand the impact freight will have in future. This is true from both a decarbonisation and network performance perspective.

Balance between outcomes and levers available

The levers available to local authorities within Transport East are not necessarily those that will have the biggest impact on outcomes. Things like road pricing or behavioural change (e.g. working from home) aren't within their scope to change.

We need solutions that will work for the whole region

There is a lot of variance within the region, both in terms of urban and rural areas, but also in terms of population. Balancing the needs of different groups in an equitable way will be important going forward.

Future model development

Our engagement highlighted a number of areas to be considered for future updates to the model

Fast scenario testing is a key feature of the ABM

The simulations are able to be 'warm started', building scenario analysis on top of existing models. This, along with automation of outputs, is useful for getting insight quickly and will be a focus for continuous improvement.

A better understanding of the visitor economy and tourism

Tourists play a vital part within the region's economy, however visitors are very different in terms of their activities and behaviours. Currently there is no real data on these visitors and their trips, and we would want to better include this in future.

Applicability to both local and regional questions

The model can answer questions at both a local and regional level. As we test new policies, we need to make this as easy as possible, and optimise for testing impacts aligned with local interventions and planning at a district level

Electric Vehicles and future fleet mixes

The current scope is focusing on levels of 'full' electric vehicle uptake. In the future, more complex understanding of different types of EVs, hybrid vehicles, hydrogen (especially for freight) is desirable to understand for the modelling.

Future public transport / rail improvements

The current future network contains committed improvements to the regional network, primarily focused around roads. The ability to test new station locations, service patterns, lines, and representation of non-passenger rail services are desirable.

Supporting scheme, design, development, and assessment

We focus the models on testing long term, strategic changes. This is suited to the beginning of an options assessment process. In time (and with appropriate updates to guidance), we will want to use the model for scheme assessment.

Modelling methodology

- Bounding the model
- Network generation
- Population synthesis
- Activity synthesis
- Data
- Model maturity

What are we specifying?

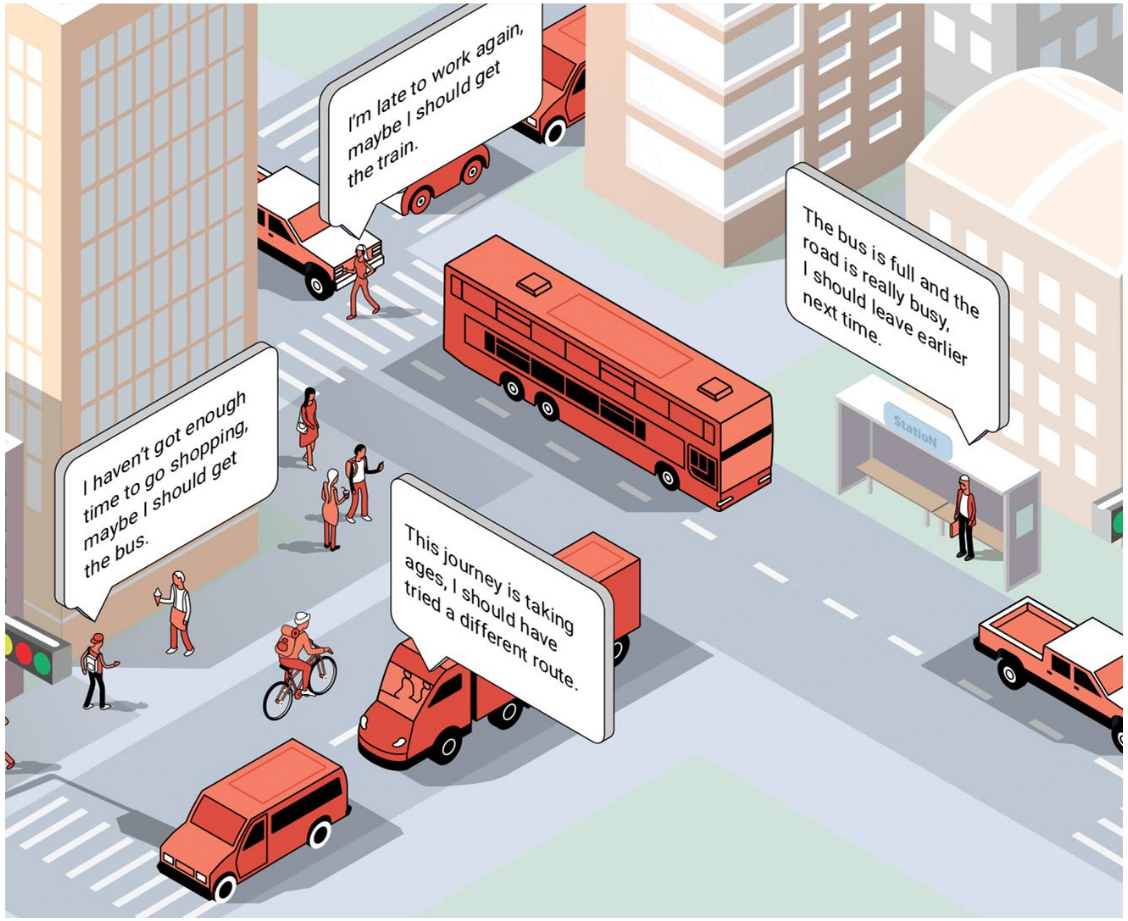
What do we need to do to create a useful model of the region?

Building any kind of model is about defining a useful level of abstraction. It is impossible to include everything in a single model, and so we need to understand the bounds in which we can work, and how we will deal with cases that stretch any limitations or edge cases within the model.

As described on page 7, we have three main things to think about; the network input, the population input, and the simulation configuration.

The simulation configuration for this model allows agents to make fully multimodal journeys and interchange between different modes (including using walking and cycling as access / egress modes).

The network and population bounds were the first things specified in building the model. Our goal was to represent the required level of network detail to enable all our agents' choices, and capturing as much national demand as possible to reflect the impact of through trips and exogenous (outside of the study area) demand.



Example agent decision making

Bounding the model - Network

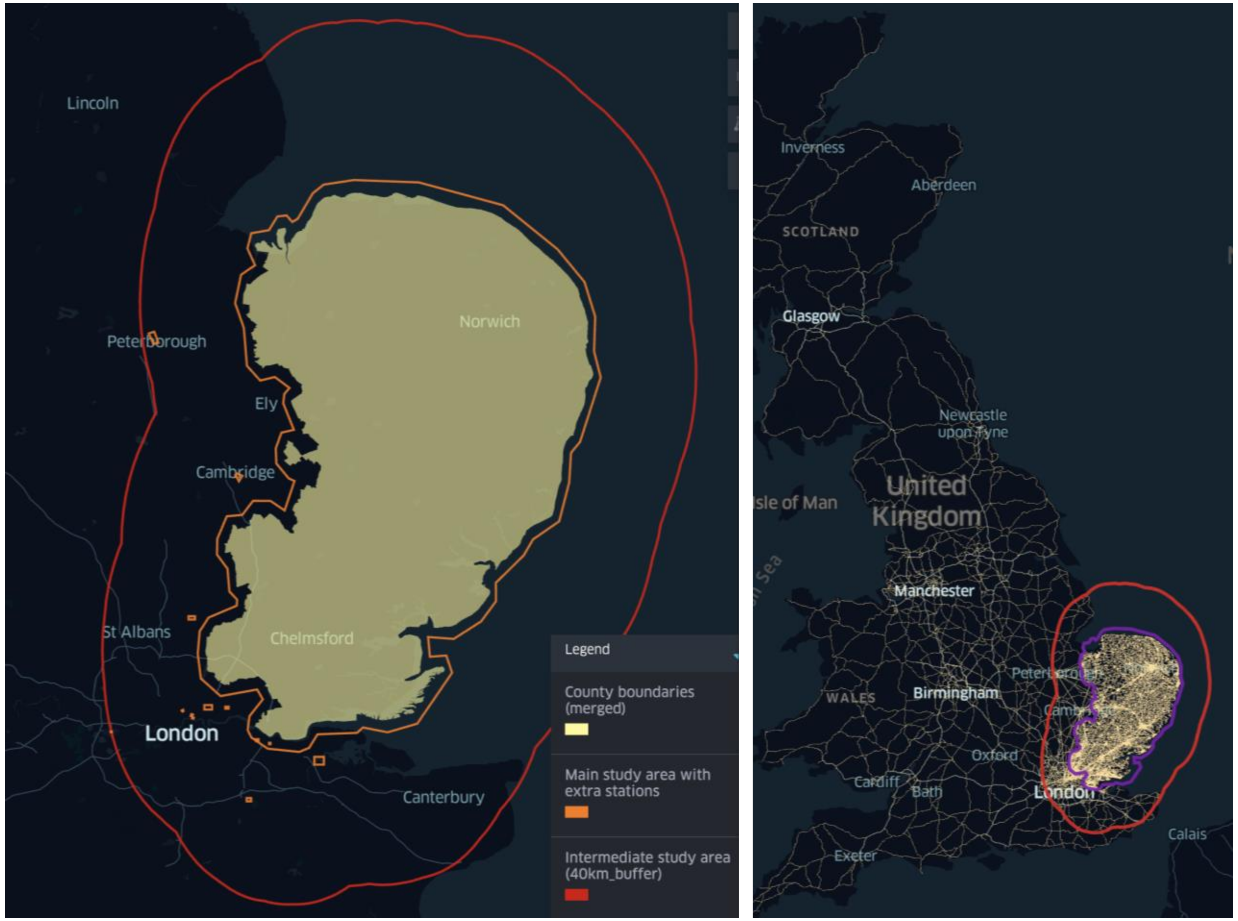
We use the whole GB network at different resolutions

We consider a number of boundaries when building the model, characterised by the level of network detail.

The boundary for the main study area for Transport East was defined by combining the boundaries for Norfolk, Suffolk, Essex, Southend-on-Sea, and Thurrock (*yellow area*), buffering the boundary by 3km and simplifying to make the polygon line simpler (*orange boundary*). This area is where we have the highest level of network detail.

The intermediate study area is a further 37km (*red boundary*) buffer around the orange boundary. This distance was chosen to include Cambridge as a key origin and destination that is outside of the formal TE region.

Outside of this area we have full mainland Great Britain strategic road network to allow long distance freight trips and is considered the buffer network.



Study area bounds (left) and full network extent (right)

Bounding the model - Population

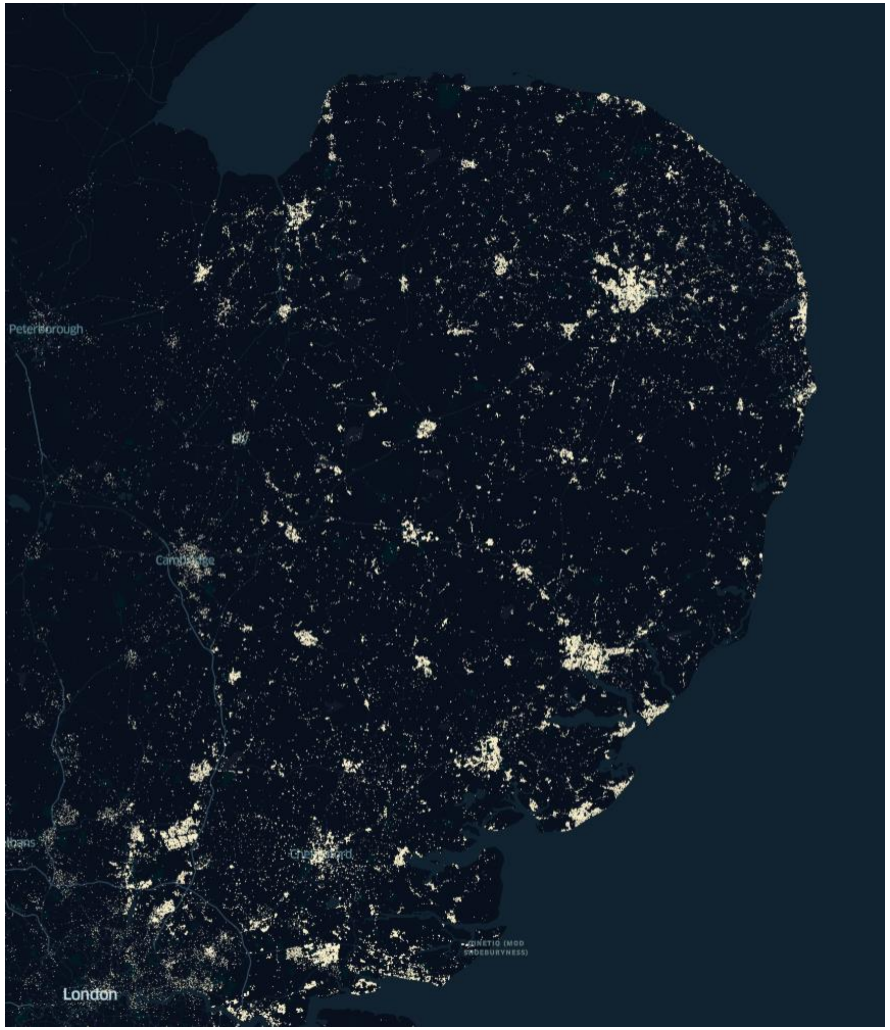
We consider journeys from across the UK that interact with the region

With a bounded network, we next need to generate the agent activity demand. Within the model there are two key types of demand; individuals travelling and freight vehicles.

For the first type of demand, a synthetic population is created consisting of agents whose activities mean they interact with the study area. This may be people with journey origins or destinations within the region, or trips that pass through the region, taking up capacity on the network. In simulation, we allow these agents to change their time, mode, and route choice.

The freight demand is generated in a similar way, however, freight tours are more complex as we generate multiple drop offs and stops for freight agents. Freight agents aren't able to make as many choices as the individual agents (they are locked to using roads).

Finally, it is worth noting that the model uses a 'ten percent' population. In this, one agent represents ten individuals. This helps reduce simulation runtime without a major impact on observed behaviour. To compensate for this, the network is adjusted to provide realistic capacities.



Agent Home Locations

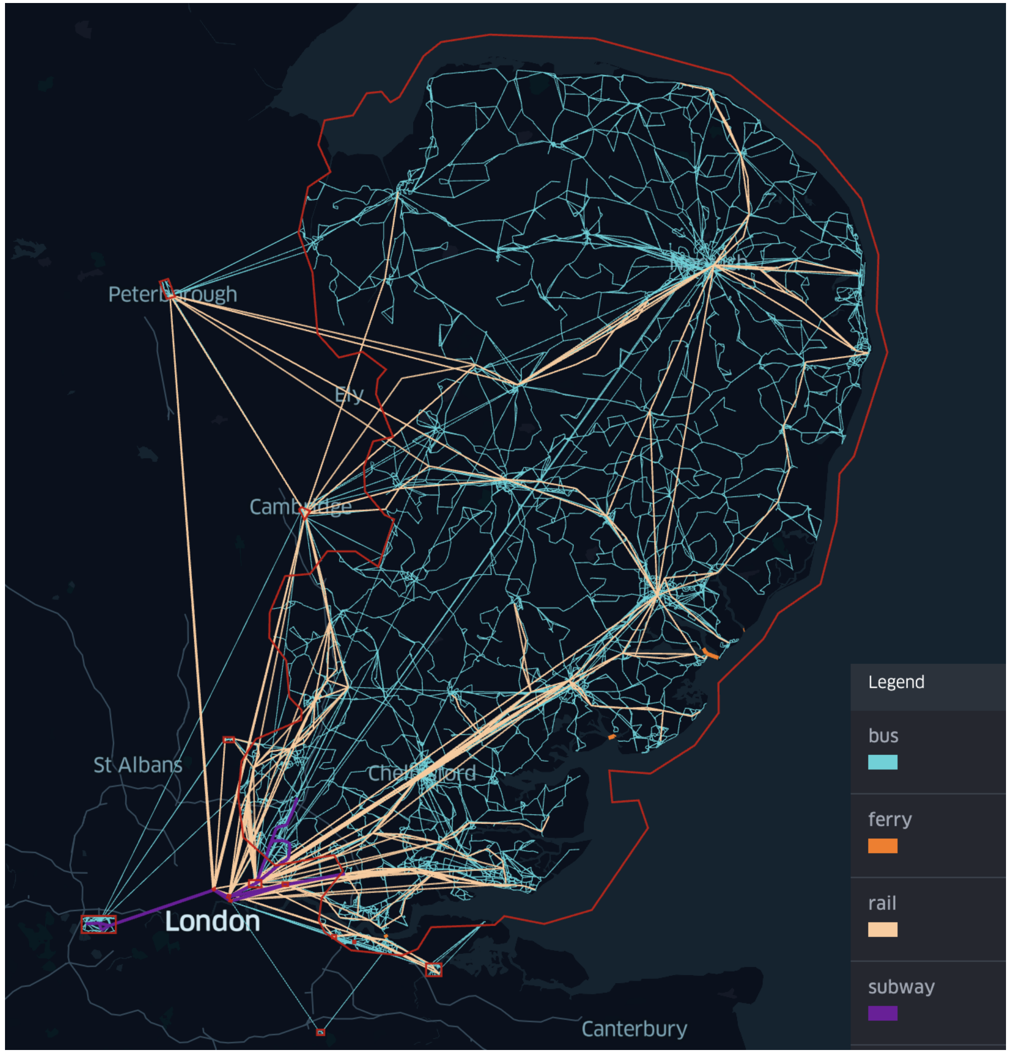
Network generation

We have a very granular network and all PT services

The road network is generated from Open Street Map based on the tags on each link. We include links with the following tags; trunk, motorway, primary, secondary, tertiary, living street, residential, service, cycleway. This means we have full detail across all five local authorities in our fully modelled area.

Public transit stations outside the main study area for key commuting routes including Cambridge, Peterborough, London terminals, and Heathrow (only subway and rail stations from T2 & T3) are included.

We adjust some agent activities to be located at these transit stops (i.e. London work trips happen at a terminus station) to remove the need for representing onward local journeys outside of the study area, meaning that the full tube or London bus network doesn't need to be included in the network.



Public Transport Services

Population synthesis

The household population captures complex information about demand

The model has a 10% population, one modelled agent representing 10 real people. Each agent is assigned a set of attributes – age, gender, income etc. and whether they have access to a car. We synthesise this population from census data, controlling against a range of aggregate statistics at both an individual and household level.

Agent households have a home location assigned and this is where their activities tours are built around. Agents chain together trips to undertake their activities, for example, going to the shops on the way home from work. This gives a much more realistic picture of demand than a traditional transport model.

Activities are sampled based on the National Travel Survey (NTS). While there are some known weaknesses in this input data, e.g. the NTS is known to underrepresent short distance trips, it provides a sound basis for our population's activity plans.

This population synthesis and activity plan generation process allows us the fine grained detail that is needed for the model.


```
----------------------------------------------------------------------------------------
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----------------------------------------------------------------------------------------
Leg(0 mode:car, area:POINT (652916.8448595409 291021.1959042467) --> POINT (652050.9117982202 303232.3674358329), time:07:2
0:00 --> 07:30:00, duration:0:10:00)
----------------------------------------------------------------------------------------
Activity(1 act:work, location:POINT (652050.9117982202 303232.3674358329), time:07:30:00 --> 16:30:00, duration:9:00:00)
----------------------------------------------------------------------------------------
Leg(1 mode:car, area:POINT (652050.9117982202 303232.3674358329) --> POINT (654055.3433836283 291568.9726628463), time:16:3
0:00 --> 16:45:00, duration:0:15:00)
----------------------------------------------------------------------------------------
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----------------------------------------------------------------------------------------
Leg(2 mode:car, area:POINT (654055.3433836283 291568.9726628463) --> POINT (652916.8448595409 291021.1959042467), time:18:4
5:00 --> 18:55:00, duration:0:10:00)
----------------------------------------------------------------------------------------
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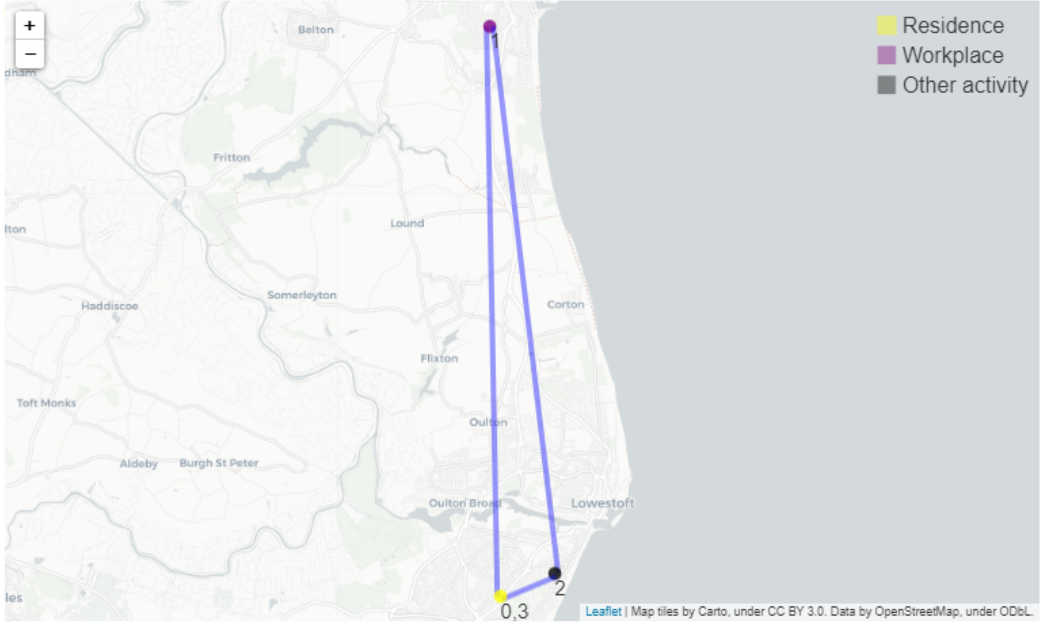


Simple Agent Activity Tour

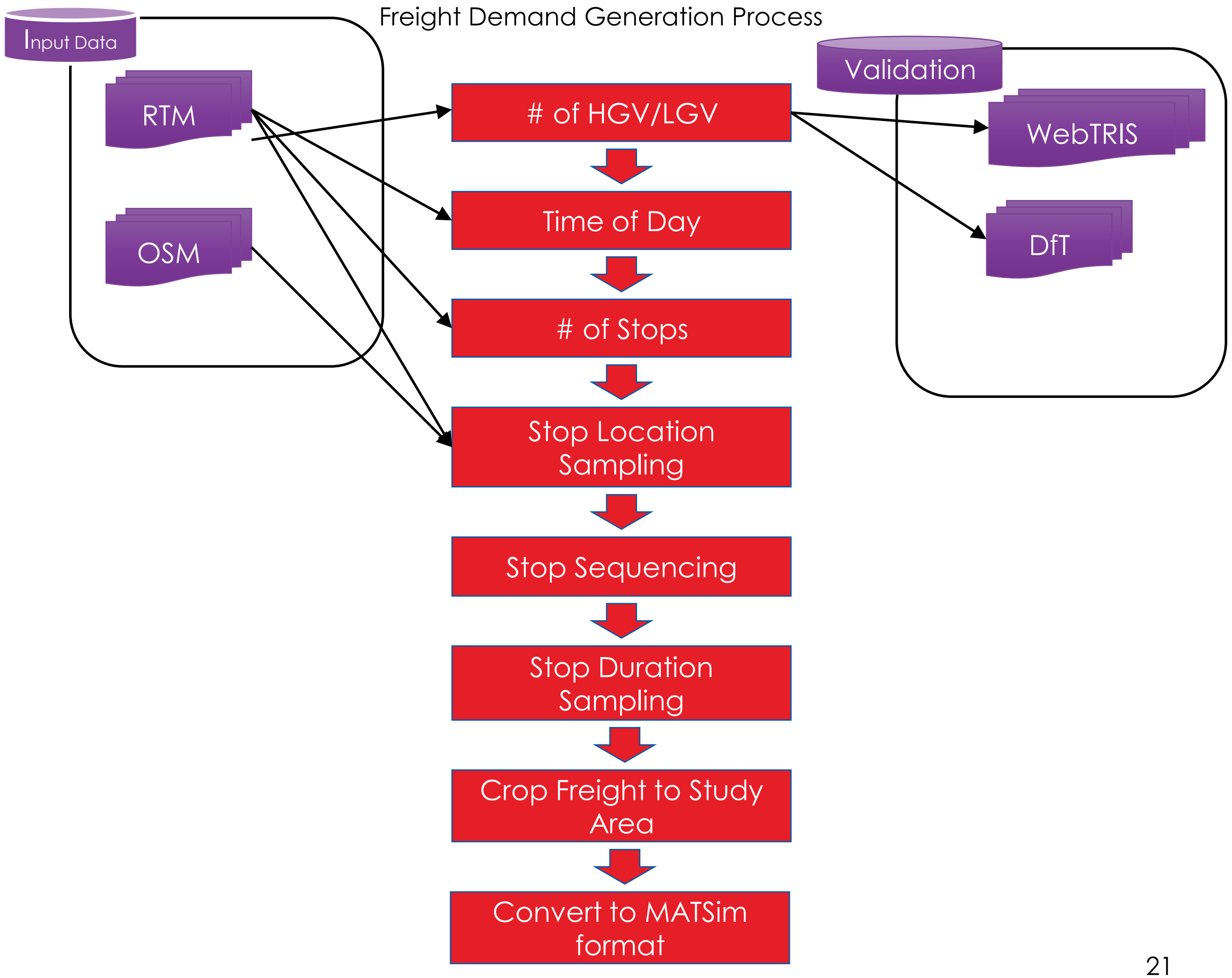
Freight population synthesis

The population generates a realistic representation of freight in the region

In addition to the demand for transport from private individuals, there is a significant contribution of demand from freight vehicles in the region. Our stakeholder engagement highlighted this as a high priority issue within the region, especially in relation to decarbonisation.

We used the National Highways Regional Traffic Model (RTM) to give us overall freight demand. This was then used to create a base set of 'tours' for freight vehicles. This captured some of their more complex behaviours, including multiple drop offs and a return to depot.

This is one of the areas where data is most scarce, and while this is a huge step forward in the representation of freight demand, additional data on freight movements would be very valuable for future iterations of the model.



Activity sampling

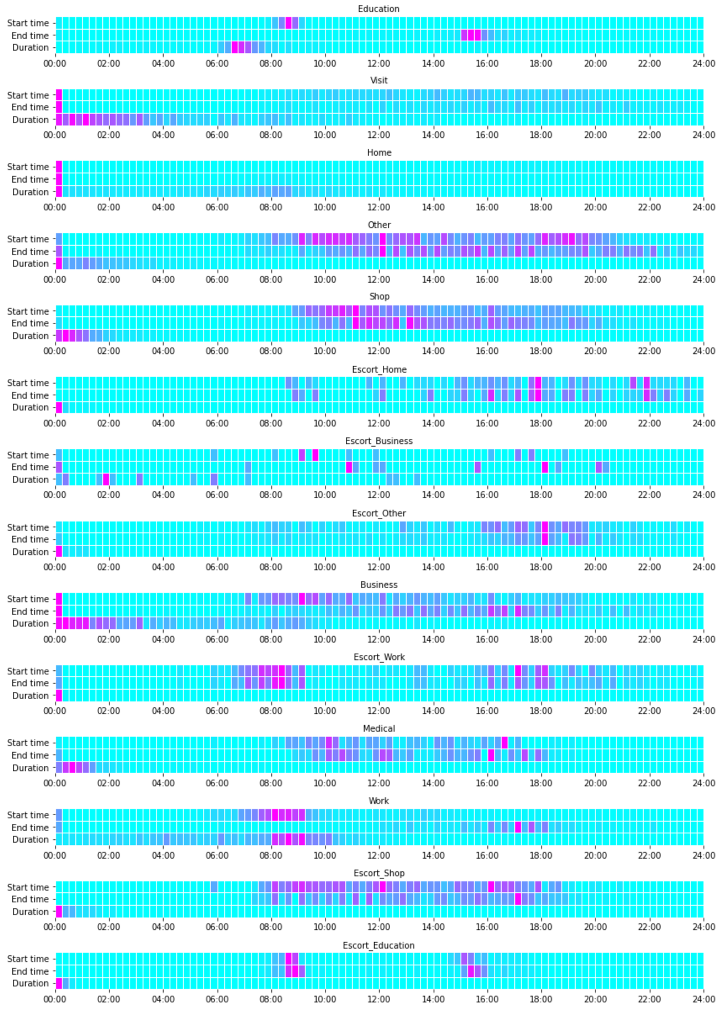
Agent activities are varied and complex

Individual agents have sets of plans for different activities. The adjacent plot shows the range of activities that we have within the model, and how they are distributed throughout the day. There are also escort activities, where one agent is travelling with another in, for example a school drop off.

We make sure that our activity time distributions are consistent with the National Travel Survey. We will discuss how we make sure that activities are happening in appropriate locations later in this section.

Activities starting at midnight in the simulation are activities that started the previous day / went over into the next day of the simulation. This is to capture this wrap-around demand when we look at the outputs of the simulation.

Agents get positive utility from completing their activities, and are penalised for being late, not being able to spend enough time at an activity, or not being able to do their activity at all.



Activity start time, end time, and duration distributions

Assigning activity locations

Agent activities are to specific locations

Each activity happens at a specific location (facility). This means that every agent travels to a specific latitude and longitude, rather than using a zonal aggregation.

We use Open Street Map tags to ensure that trips are going to the correct locations, i.e. education trips go to schools, colleges, and universities. The input data for activity locations is zonal, so we select a facility of the right type in the right zone for each agent. This is done across private and freight demand – and is controlled back to known demand and facility data.

Finally, in areas where there is demand and no appropriate facility (i.e. gaps in OSM data), these are synthetically generated and added to the network.

Norwich Facility Visualisation

Data

What data do we use to build an ABM?

The ABM approach allows us to be flexible with the data sources that we use. Within the UK we use the following as our primary inputs to the simulation:

- UK Census Data: Population and demographics
- National Travel Survey: Travel diaries and activity plans
- Consolidated GTFS data: Public transport services
- OpenStreetMap: Networks, facility information
- National Highways Regional Transport Models: Freight demand

We have also used a range of additional data sources from National Highways and the individual authorities in Transport East to provide benchmarking and validation.

Future year models were underpinned by assumptions from Office of National Statistics, the Department for Transport, and local development plans and set out within the forecasting section.

OpenStreetMap Facility Data

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Model maturity

This is the first version of the ABM, and we expect it to increment and iterate in future

This report reflects the outputs of a model that has had four months of development and iteration. We have undertaken benchmarking in order to understand the simulation's performance and identify areas for future improvement.

In contrast to a more traditional model, the simulation can be updated with new data on an ongoing basis. We consider the TE models to be at a high 'Alpha' or low 'Beta' level of maturity, with some additional new features added beyond those used on the Suffolk County ABM:

- Multi-modal and inter-modal access and egress to selected public transport stations (e.g. bike -> bus -> walk -> train -> walk)
- Synthetic delivery tours for freight agents
- EV subpopulation to allow EV costs to be different from combustion engine vehicles
- Variation in monetary cost responses by income group

This model is ready to test real world scenarios and support real world policy decisions. The scenario insights section of this report gives an initial overview of some of our first findings.

Proof of Concept – Initial iteration of the model – bounded area with automated network and population generation. Not for insight generation.

Alpha – Initial functional model with benchmarking. Able to produce useful insights, and highlight future development opportunities. Lower assurance.

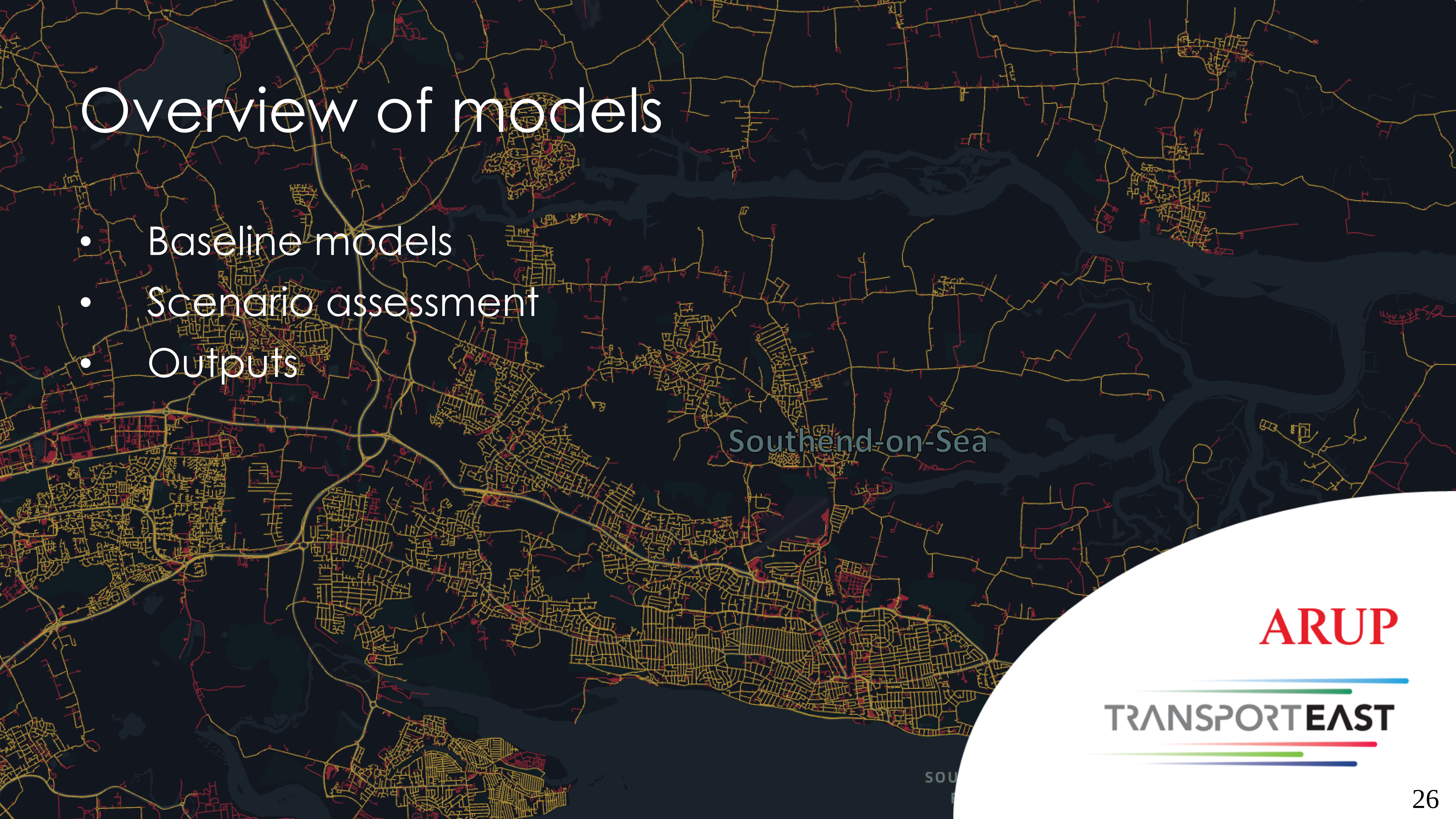
Beta – Alpha with enhancements to answer specific questions, with additional refinement of data and validation in these areas. Higher assurance.

Formal Calibration and Validation – Formal calibration and validation in line with DfT guidance (initial guidance is being developed now but this will take a longer time to realise).

Mature Model – Mature model with a high level of assurance and established best practice processes for testing different scenarios and schemes.

Overview of models

- Baseline models
- Scenario assessment
- Outputs



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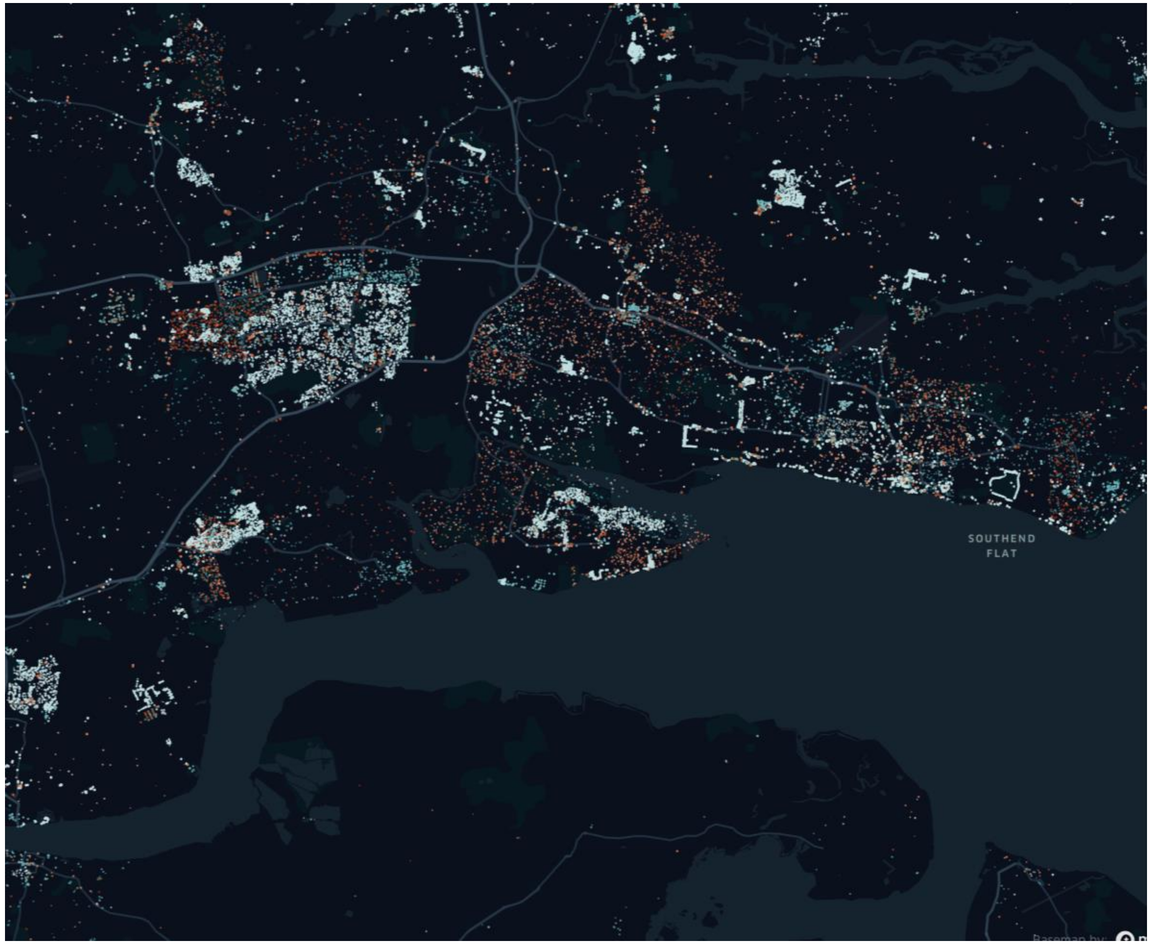
Baseline models

We have built models to represent 2019 and 2040

Our two baseline models are intended to provide different insights and outcomes. We chose a **base year of 2019**, as this is the year where we have the ability to use most data, as it was before the COVID-19 pandemic. This means that we can use a variety of different benchmarking data from different sources to judge the performance of our model. This is especially important when we are using data from a wide range of different sources across the five separate local authorities that make up Transport East.

The future year we selected to model was **2040**, to align with decarbonisation targets. This means that there are a number of key outcomes to be achieved by this date, but also that there are publicised assumptions and future forecasts that can be used. We are not trying to create a formal 2040 forecast – we want to understand the behaviour of the future network so that we can understand agent responses as we change things.

We have therefore created a 2040 Baseline model which incorporates some expected changes, to serve as a basis for comparison with future scenarios.



Southend-on-Sea Facility Locations

Scenario assessment

What did we test with the model?

The stakeholder engagement identified a large number of different scenarios and impacts that we would want to test with the model. Given the timeline and scope for this project, we have focused on some of the key factors that we believe will impact the decarbonisation of the Transport East region by 2040. These simulations were run in addition to the 2019 and 2040 baselines. Detail of the specific changes to the model can be found in the appendix.

Scenario	Research Question	Changes to Baseline
2040 - Road Pricing Scenarios	What is the impact of increasing per km costs on driving?	Cars, LGVs, and HGVs have their per-km charges increased. This will be across combustion and electric vehicles. Increases; Low: 1.5x, Medium: 2x, High: 3x. These are applied across different vehicle types based on their base 2040 cost per km in the TAG Databook (so EVs remain cheaper to run than combustion cars, but cost more than in the 2040 baseline).
2040 - EV Uptake Scenarios	What is the impact of different levels of EV uptake?	The 2040 Baseline has 33% of private vehicles as Electric Vehicles based on TAG Databook data. We have a scenario at 66% uptake and one at 88% uptake (based on the Vehicle Led Decarbonisation assumptions in the TAG Common Analytics Scenarios). Different EV proportions applied to LGVs, and HGVs assumed to be all combustion (as per TAG data book).
2040 – Active Travel	What would happen if active modes were twice as appealing?	We halved the utility cost of walking and cycling (representing agents having a more positive attitude to these modes). This isn't saying how this could be achieved, but rather considering the impacts from this improvement.
2040 - Combined Scenario	If we combine scenarios, how close do we get to net zero?	This final scenario combines the highest level of road pricing used above, with the highest level of EV uptake, and the active travel utility boost.

Outputs

An ABM produces vast quantities of output

An ABM outputs a large quantity of data – recording what every agent did at every second of the day. We also have huge detail in the model, since we can look at the behaviours of as many subpopulations as exist in our input data.

This presents some challenges when looking at the model outputs – and we focused on the following analyses in this initial model build phase. .

Network Performance: This is predominantly a focus for benchmarking the 2019 model and comparing it to the 2040 baseline. We ask questions like; how does the network perform? Where do we see delays and congestion on the road network? How many people are using public transport? What are the mode shares? What mode shares do we see for short distance trips?

Mode Shift: When we look at scenarios, we want to understand which agents have switched between modes and for what reasons.

Agent Utility Analysis: This is closely related to mode-shift. For this analysis, we look at agents' selected and unselected plans, i.e. all plans that were in the agent's top five options but weren't necessarily selected in this final iteration. We then compare the utility of these plans to get some insight into modal choices for different agents. For example, this lets us identify agents who had the potential to shift to viable trips on different modes but didn't – highlighting where 'nudge' behaviour interventions could be most beneficial.

Equity: One of our key outputs across all of the analyses we do with the model is looking at how different groups of people are impacted differently. For this study we are focusing on disaggregating impacts by agent income, gender, and age group.

Carbon: One of the most exciting insights we can generate from an ABM is the amount of emitted carbon at a much more detailed level. We look at vehicle speeds and fuel types across all individual links in order to build up a picture of where carbon is being emitted with a much higher level of temporal, spatial, and agent detail.

These analyses were undertaken as appropriate for the selected scenarios. We highlight key findings in this report.

2019 Baseline

- **Overview and model performance**
- Benchmarking

ARUP

TRANSPORT EAST

2019 Baseline overview

A baseline we can benchmark and use to test near-term scenarios

The 2019 Baseline model is important because it allows us to build a model based on as much real, observed data as possible. This allows us to benchmark the model against reality, and adjust the simulation configuration so that it replicates local characteristics.

This simulation configuration is then used with the updated 2040 network and population to produce the 2040 baseline. This creates consistency between the behaviours in each of the simulations, which is needed as we project the model into the future year scenarios.

In this section we describe how the 2019 baseline model preforms, i.e. what we see from the outputs at the end of the simulation run. The next section on Benchmarking then considers how this behaviour compares to observed data.

Thurrock Road Network

2019 Baseline network performance

Trip statistics and mode shares

The Transport East region is very large geographic area, with a significant proportion being rural. This means we expect a larger share of journeys to be undertaken by car.

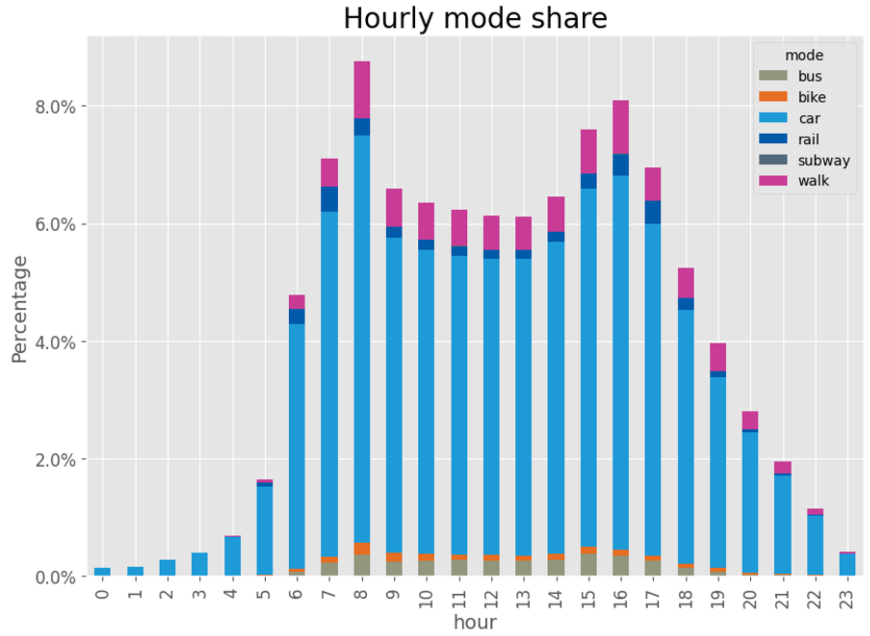
With the detail provided by the simulation, we can extract comparable travel statistics by different modes across the full day as illustrated in the adjacent table and graph.

Most trips made are private car trips, representing more than half of the travel in the model (61% of trips, 51% of travel time, and 62% of distance).

The graph shows the model has a morning peak (0800-0900) and evening peak (1600-1700), most pronounced for car trips. The bus trip profile is in line with the bus operation hours and travel behaviour, where most trips made are in the peak time as well as inter-peak for non-commute activities.

The bus speeds include access/egress/waiting hence slightly low. The walking and cycling speeds are adjusted to accommodate the simulation assessing them as straight-line trips.

Mode	No trips	Total travel time (min)	Total distance (km)
HGV	1,015,770	32,229,930	25,840,322
LGV	926,290	30,986,929	25,847,834
Car	5,727,550	148,892,959	116,117,751
Bike	139,840	2,344,548	584,198
Bus	334,750	14,853,940	3,572,615
Rail	319,970	24,245,650	13,241,993
Subway	7,880	543,542	227,871
Walk	860,550	37,275,771	1,865,451
Total	**9,332,600**	**291,373,267**	**187,358,034**



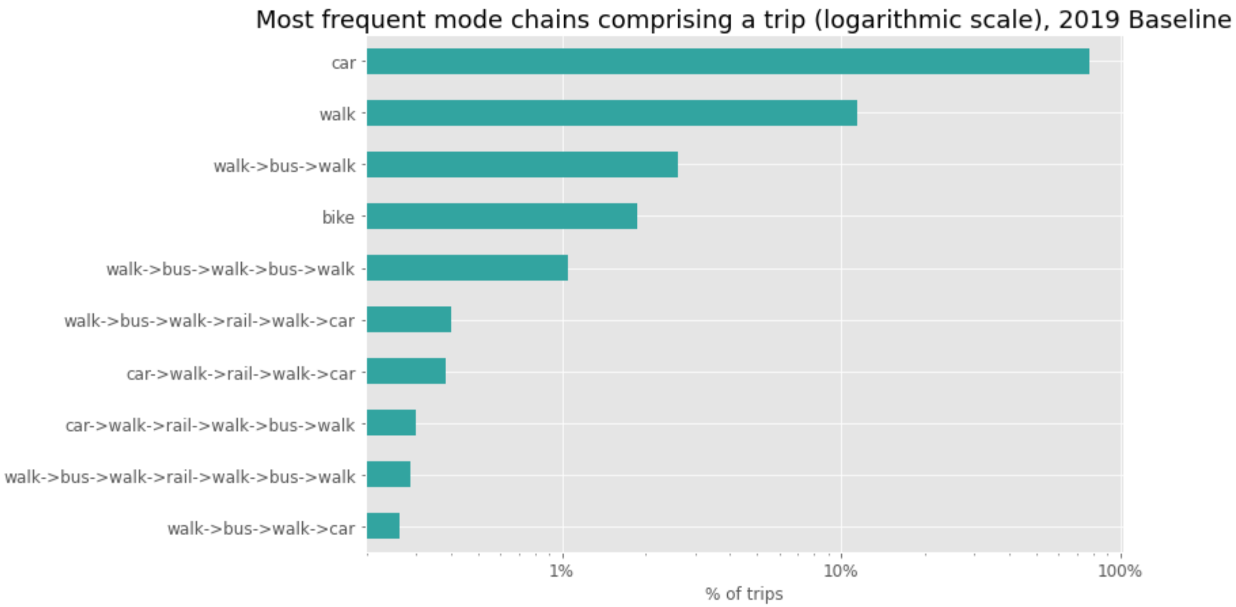
2019 Baseline multimodality

Agent trips are inherently multimodal and allow intermodal trips

The simulation is full multimodal and allows agents to make intermodal trips, with agents being able to shift between individual modes or use combinations of modes in order to fulfil their plans. For our analysis, a trip is between two activities, and a trip can be made of multiple legs. For example, we would expect all public transport trips to involve at least one other mode, so that the agent can access and egress from the bus stop or train station to their activity location.

We predominantly discuss trips in our analyses, and these are assigned to the mode of the longest leg. However, it is worth considering the range of intermodal legs that agents make in the model.

The chart on the right shows the most common leg patterns, these chains represent the household agents only (as the freight population cannot change mode). For this population, car only trips are 77% of legs, and we use a logarithmic scale for clarity. Only car, bike, and walk trips use a single mode, and we have some very complex leg chains. They are also direction, so the walk-bus-walk-rail-walk-car is likely a trip home where the agent has used bus followed by rail to get back to their car for the final leg home.



This mix of modes, plus agents walking between different stops or stations shows that agents are exploring very complex choice sets in the simulation that reflect realistic options available to them.

Note, car in this output does not differentiate between owned cars, car passengers, or taxis (which agents can use at a higher cost than driving their own vehicles).

2019 Baseline network performance

Daily car flows

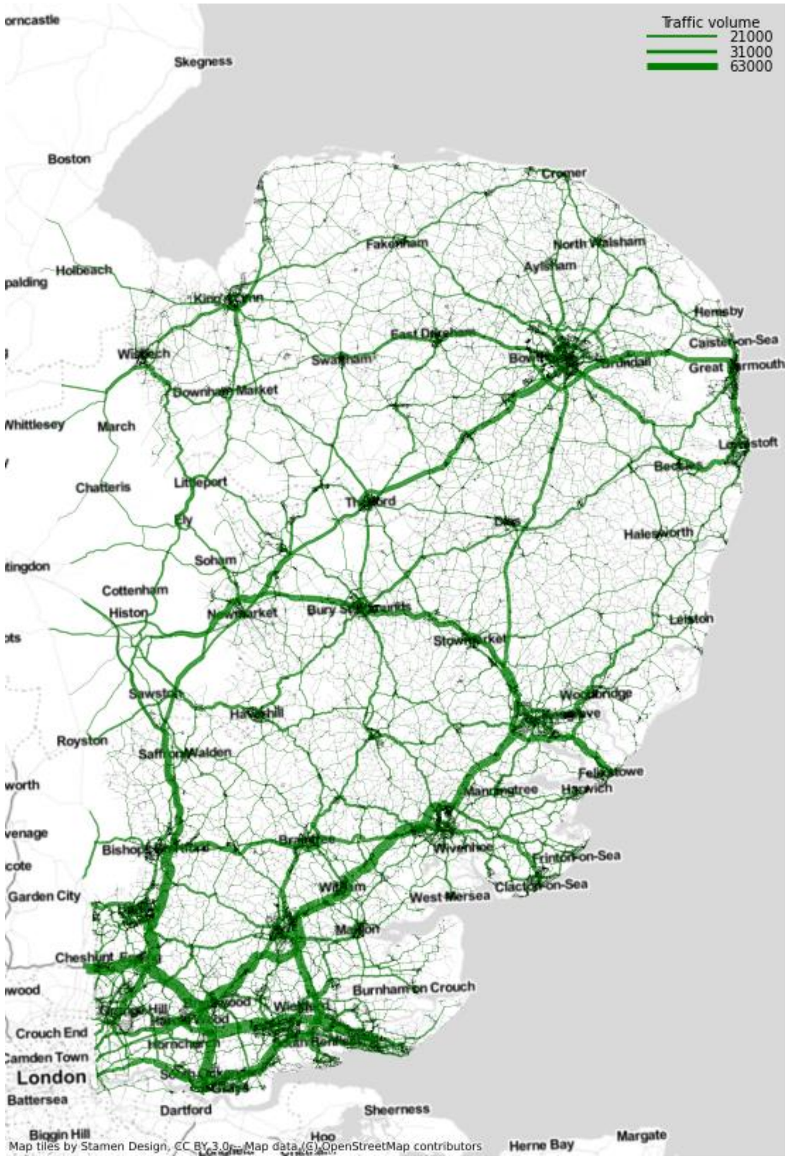
The adjacent plot shows daily car flows in the 2019 baseline model. This shows the model generates high traffic volumes on the M25 and the rest of the motorway network in the model area, particularly near London, Chelmsford, Ipswich and Norwich.

Key strategic corridors such as the M11, A11, A12, A13 and A14 are clearly visible, along with the large rural areas of the region with low levels of traffic.

The next page shows equivalent flow plots for the AM peak (8AM-9AM), inter-peak(12PM-1PM) and PM peak (4PM-5PM). The distributions are similar, while overall flows in the PM are highest. The expected reduction in demand during the interpeak is also visible. The Strategic road network (SRN) and Major Road Network (MRN) are clearly visible from the high flow volume links within the model.

The high-level plots give confidence that vehicles within the 2019 base model at an aggregate level are using key road corridors.

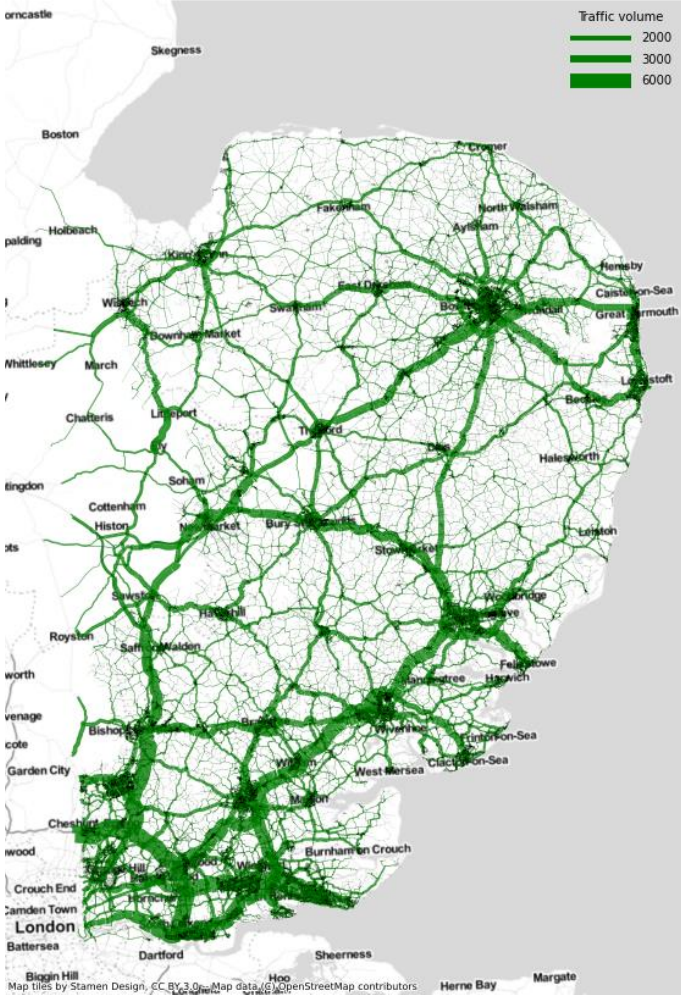
Link flow, TE, total



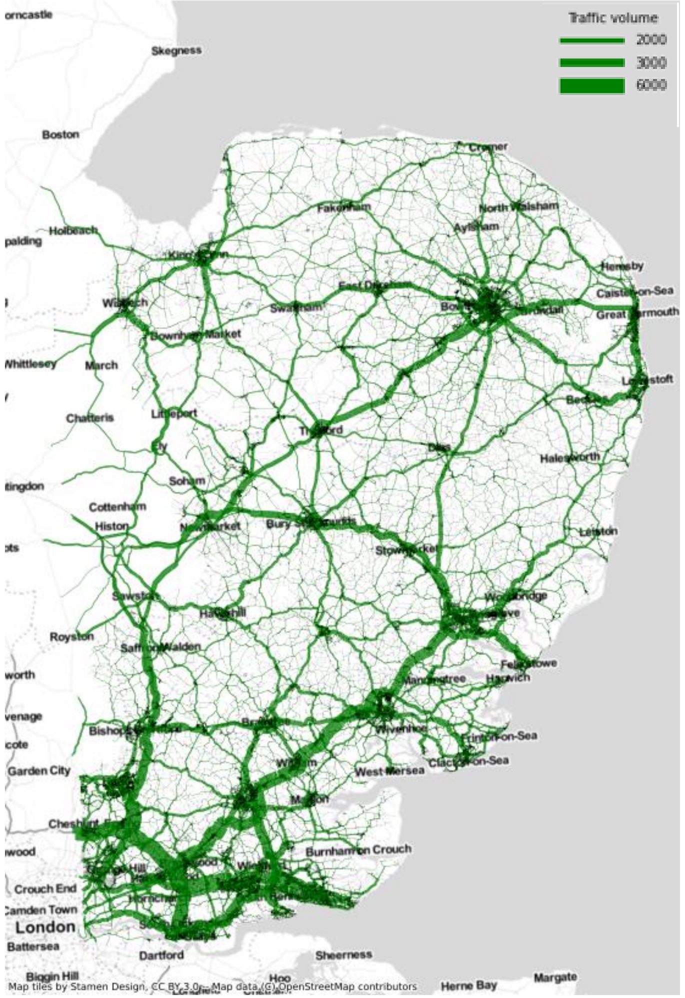
2019 Baseline network performance

Peak and interpeak car flows

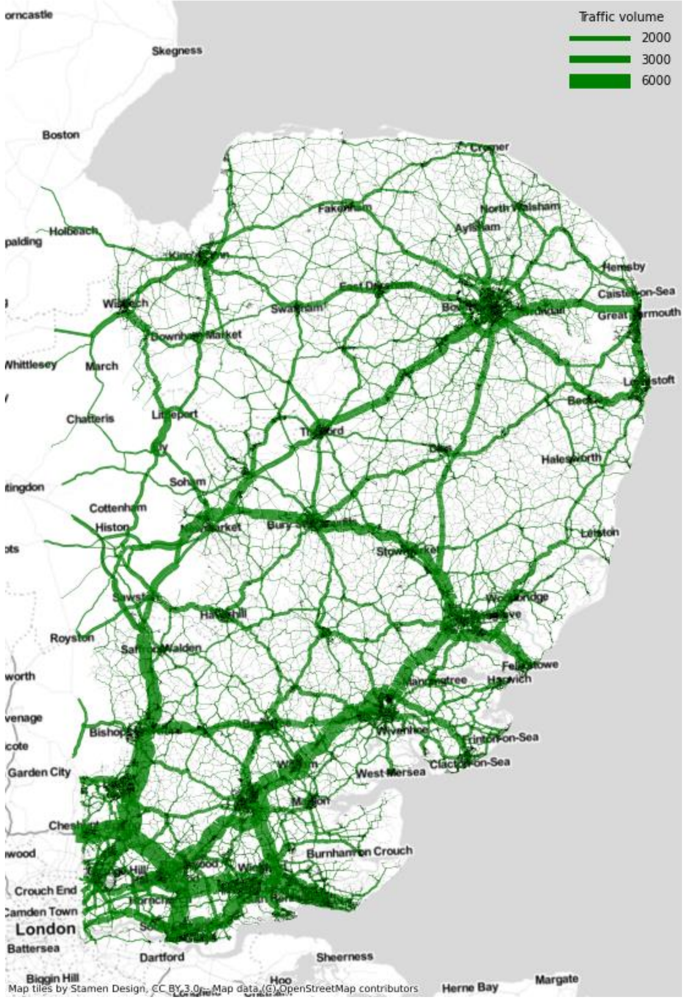
Link flow, TE, 8



Link flow, TE, 12



Link flow, TE, 16



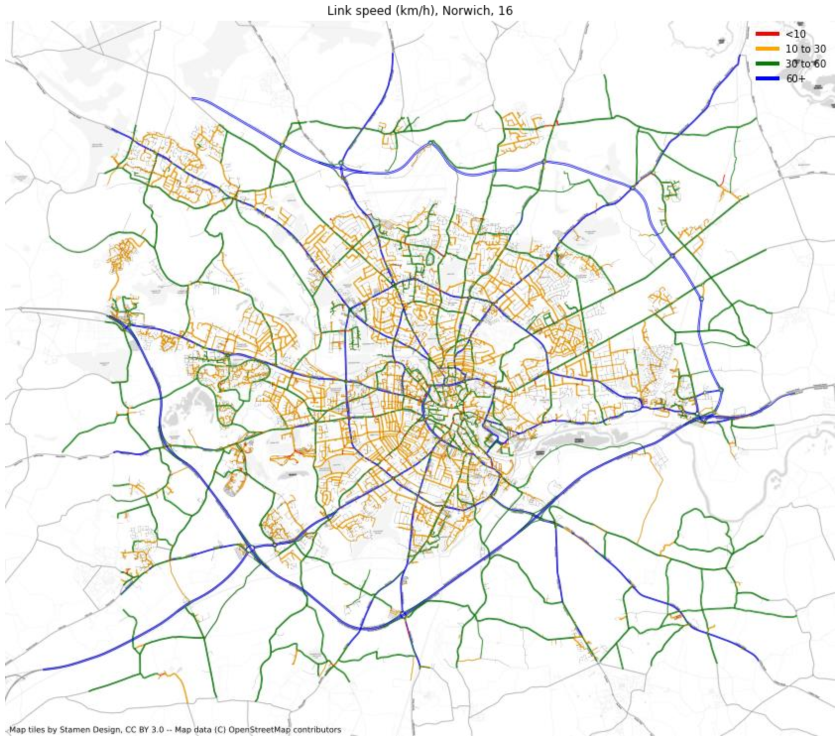
2019 Baseline network performance

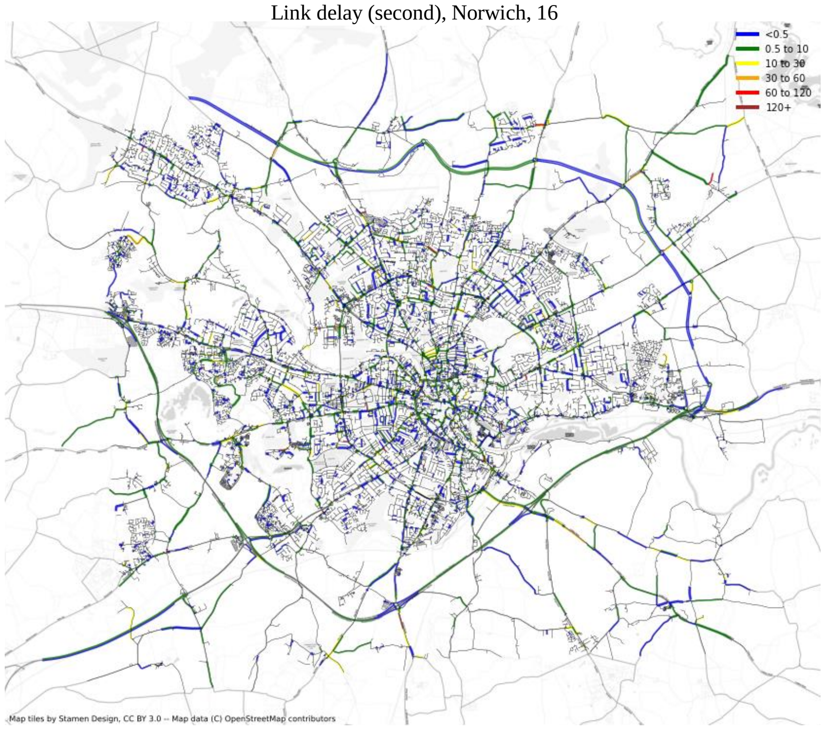
Car speeds(km/h) and delay(seconds)

We can generate detailed speed and delay plots within the study area. The example on this page show the evening peak hour in Norwich.

The link speed plot clearly demonstrates the higher speeds on the SRN links and ring road with speeds in excess of 60km/h. Conversely, minor residential streets within the model are as low as 10-30km/h with distributor roads and rural routes in the 30-60km/h range.

The link delay plot shows a range of delays across the network, minor arms in the town experience delays of 10-60 seconds and some approaches to more major junctions have delays of 60-120 seconds. Overall, the plot shows the study area generally coping with traffic volumes in the period.





2019 Baseline network performance

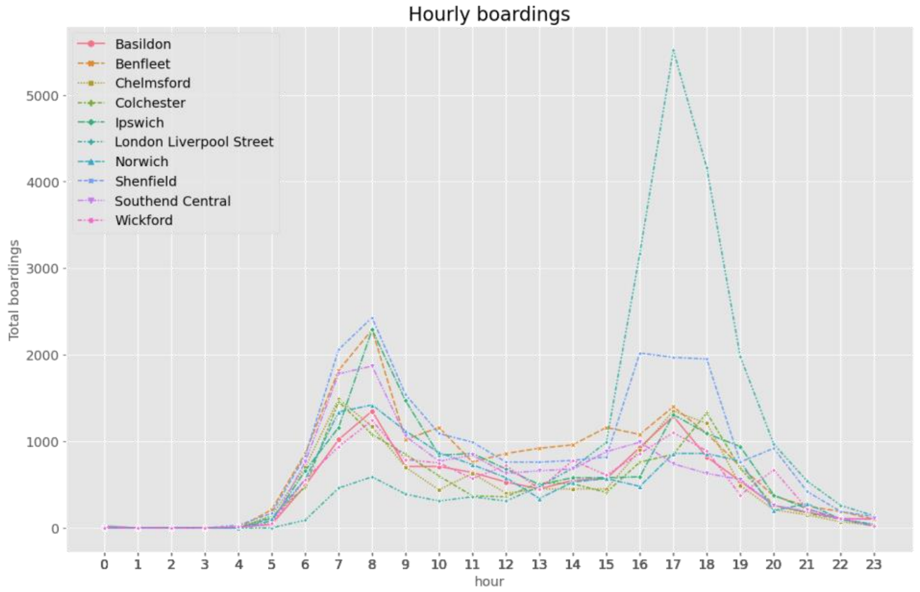
Rail ridership

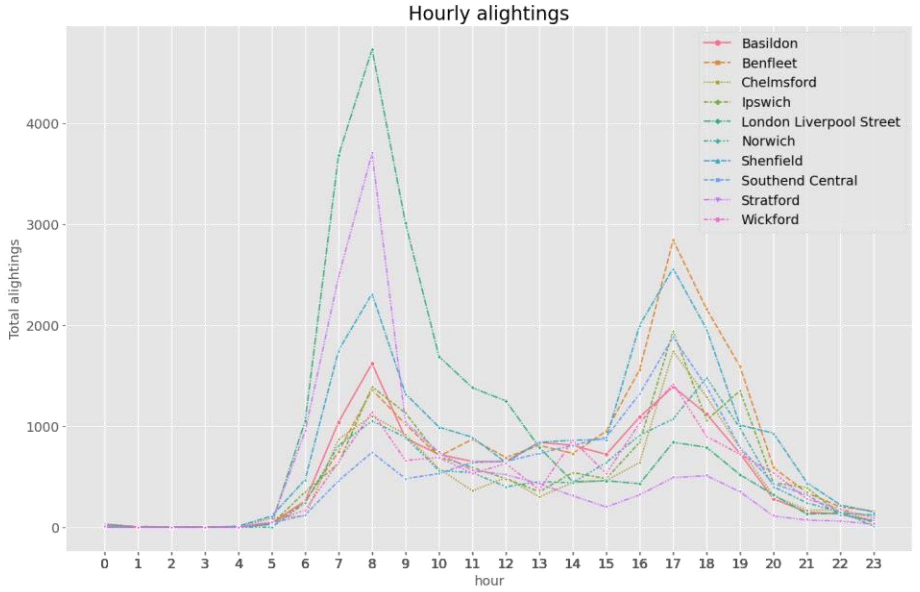
For historic reasons, there is more data about the performance of the road network than that of the non-car modes. Public transportation has some data about ticketing and ridership, however the available data is not suitably granular for us to properly benchmark. However, detailed analysis of rail behaviour can be extracted to understand how agents are interacting with the rail network.

The charts show the modelled ridership throughout the day at the ten busiest railway stations in the study area in respect to boardings and alightings. The stations are located in major towns and cities in the Transport East region and London.

Overall rail demand within the model is heavily dictated by commuting into London, with London Liverpool Street and Stratford as two key interchange points. This pattern is reflected well in the summary charts showing large peaks in alightings at these stations in the morning peak and similar peaks for departures in the evening peak. Shenfield also has significant alighting in the morning peak, likely as a result of it being a key interchange point for mor minor stations on routes into London.

The top 10 stations align with major towns and cities in the region and those with the highest frequency services showing that major rail routes are used by agents within the model.





2019 Baseline network performance

Bus ridership

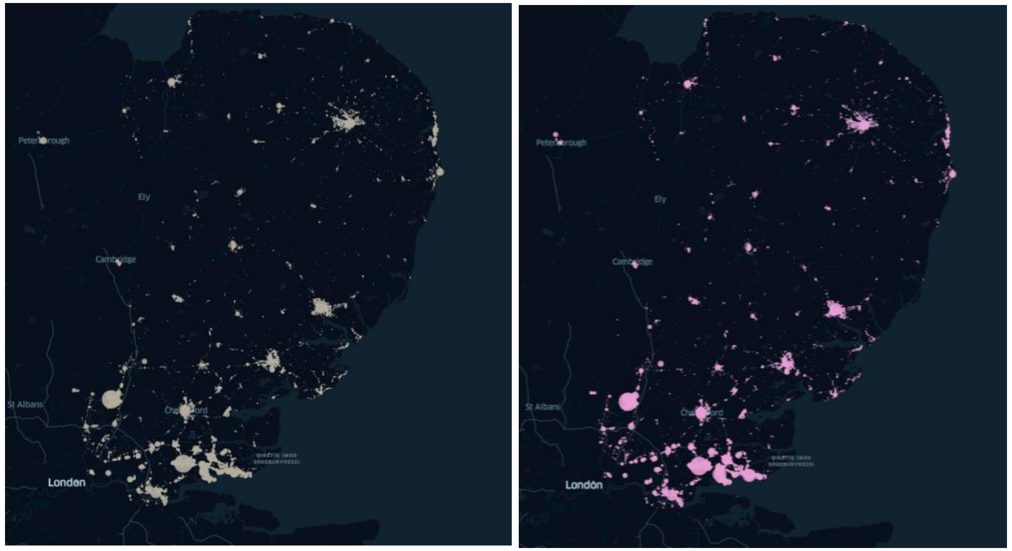
In a similar way to rail, we are able to look at the usage of individual bus stops, bus occupancy, and wait times. However, model outputs can be reviewed to ensure agents are interacting with bus services appropriately. Bus supply we know is a faithful and complete representation of the published timetables, and every service is modelled.

The regional figure shows that total daily bus boardings are heavily dominated by main urban areas that have higher levels of public transport provision, while many rural areas have very few trips.

The granularity of the model has been used to produce visuals of individual bus stops in Chelmsford. Boardings and alightings in this extract are consistent across the day, with some asymmetrical flows. More passengers board from west of Chelmsford railway station than those alight here, whereas the opposite in the east of the railway station. This also shows these key interchange points (bus and rial station) as the busiest stops with the town.

With more detailed bus occupancy or ticketing data we would be able to measure performance better and provide formal benchmarks. However, public transport performance in the model is providing sensible, representative behaviour that can be reviewed further in later model versions.

Total daily bus boardings and alightings Transport East



Total daily bus boardings (left) and alightings (right) by stop in Chelmsford

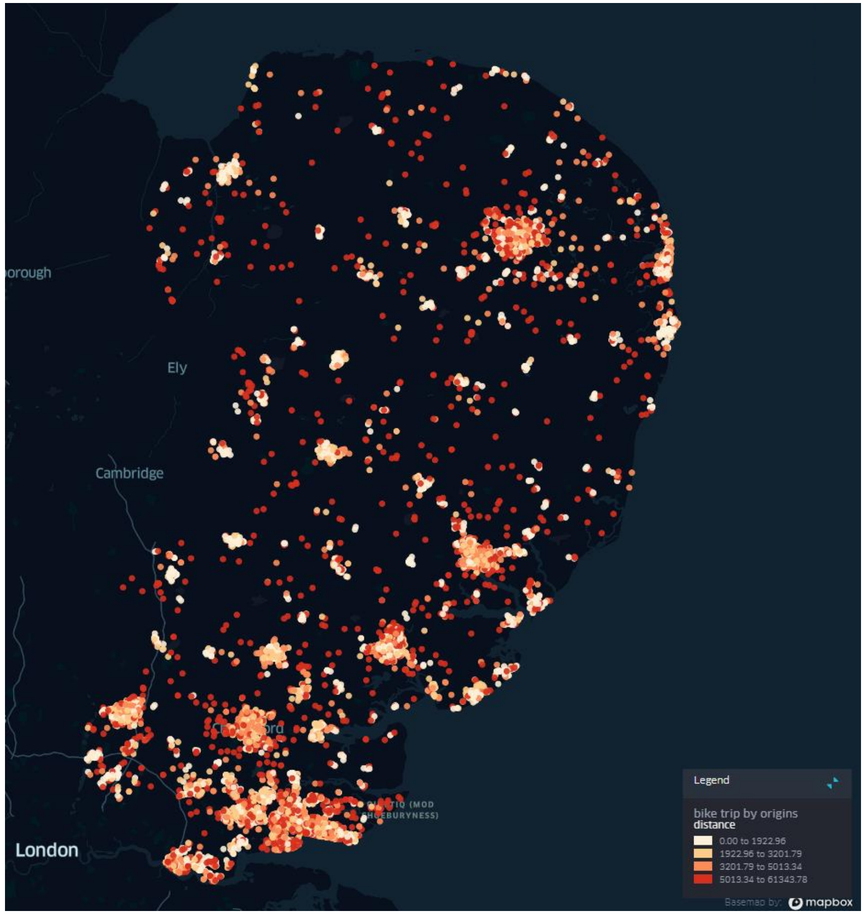
2019 Baseline network performance

Active modes – cycling

The figure to the right show the origin of cycle trips, coloured by distance across the region. We must remember that cycling represents under 1% of all trips in the baseline. We see a realistic distribution of journey distance, with trips clustering around urban areas where there is more residential land use. In rural areas, we see more cycle trips over 5km in distance, reflecting the longer distances that agents need to travel to undertake their activities.

Cycling provides a number of challenges when we model it within an ABM. As a mode of transport, cycling has a huge number of benefits; it is cheap, reliable, and is ideally suited for shorter distance trips. However, there is a tendency to overestimate cycling trips as agents in the simulation only consider these factors, and not many of the other factors we know are important like the availability of secure cycle parking, changing facilities, and the perception of road safety.

We see more detail of the potential for cycling to capture shorter mode share as part of the short trips analysis. We will also see how active modes impact the simulation more generally through analysis of the active scenario.



Origin of cycle trips, coloured by distance

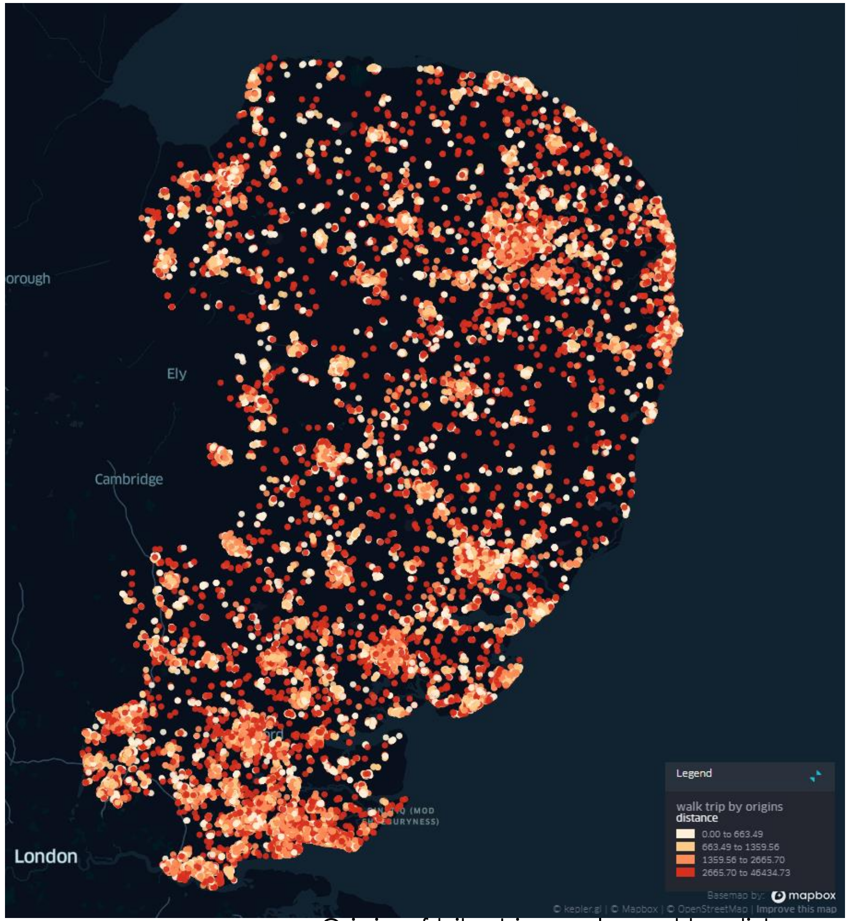
2019 Baseline network performance

Active modes – walking

We see the same visualisation for walking trips, but with many more trips across the region, reflecting walking's position as the dominant mode for the shortest trips. In urban areas, the distances of walk trips range from few hundred metres to above 2.5km, whereas the distances in rural area are mostly above 2.5km. These are trips where walking is the dominant mode, so this behaviour is expected.

The trips shown here are likely to be almost all walking only trips, as dominant mode is defined as the mode which was used to travel the longest distance as part of a trip.

Walking is also a component of almost every multimodal trip across the model (see page 33) and therefore we should also consider the impact walkability has on all non-car modes as an enabler of longer, non-car journeys. The ability to grow walking mode share is discussed as part of the short distance trips analysis.



Origin of bike trips, coloured by distance

2019 Baseline network performance

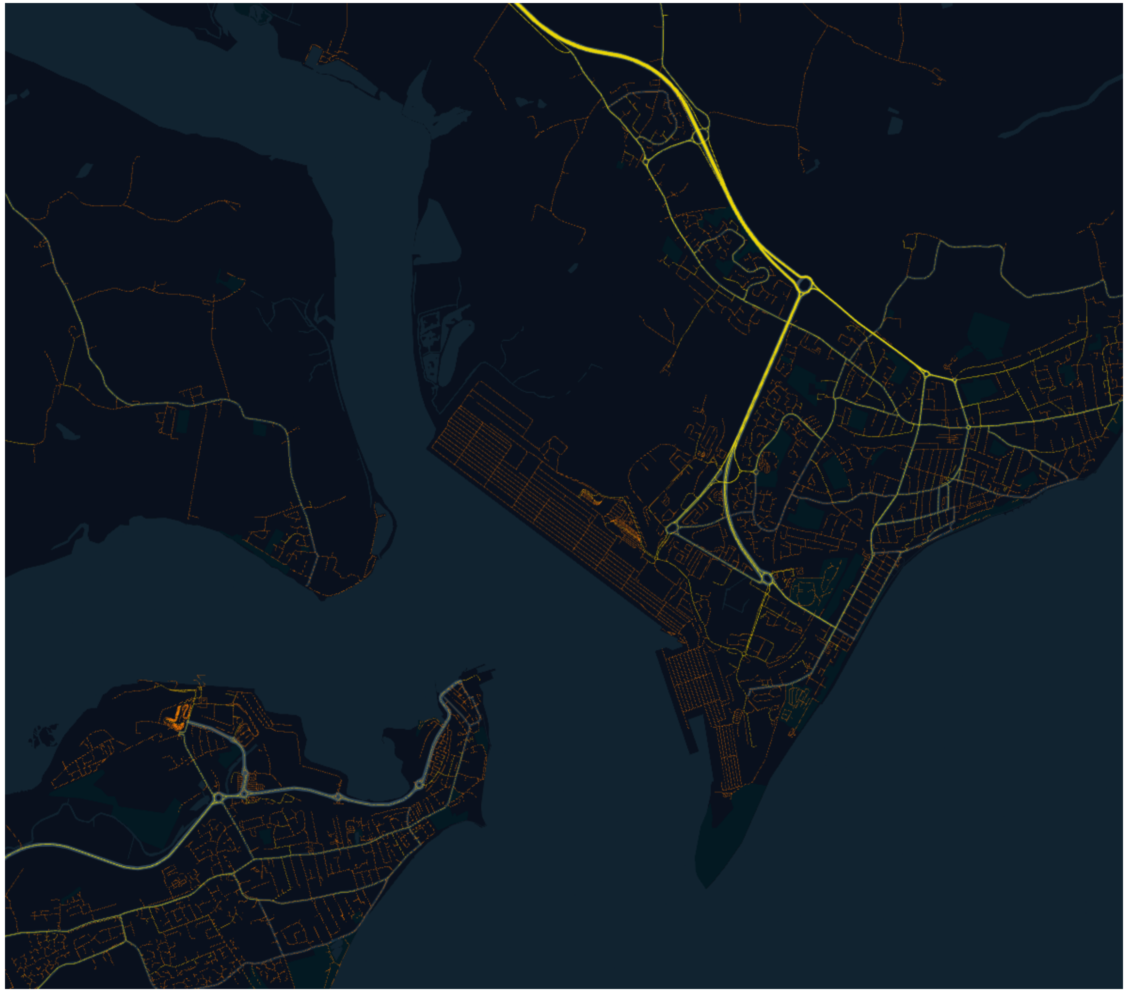
Overall commentary on model performance

This section has provided high level data from the 2019 Baseline model for each mode of travel to demonstrate that the supply of transport infrastructure combined with the demand generated by the agents completing their daily activities are interacting with each other and making sensible choices at an aggregate level.

The outputs show that total trips by mode, time of day, distance and travel time are realistic and align with typical expectations for transport networks.

Car outputs show that main trunk roads corridors within the model, along with urban centres and ring roads are all well represented with speed reductions in and around busy centres. Rail and bus movements replicate known key demands and corridors in the region and are profiled through the day aligned to logical expectations for the types of trips.

The next section of this report moves beyond the high level of behaviour in the model and focuses on how the model benchmarks against directly observed data.



9am hourly traffic flow – Felixstowe and Harwich

2019 Baseline

- Overview and model performance
- **Benchmarking**

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TRANSPORT EAST

2019 Baseline benchmarking

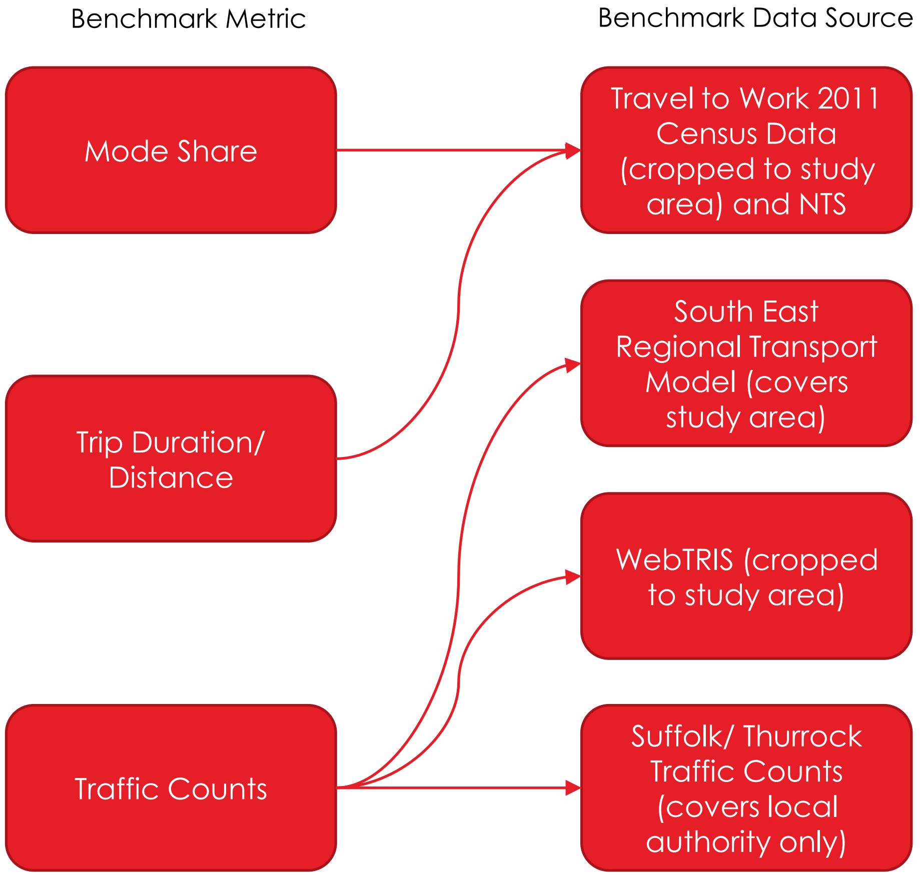
Overview and purpose

We have undertaken a thorough benchmarking exercise to compare our model outputs with a variety of observed data sources. Recognising that the benchmark data itself is not a perfect reflection of human travel patterns and behaviours, the main purpose of this exercise was to ensure that our model outputs are sensible, and comparable to the observed data.

Data sources used as part of the benchmarking process include:

- Travel to work 2011 Census data (mode share/ trip data)
- National Travel Survey (mode share)
- South East Regional Transport Model (count data)
- WebTRIS (count data)
- Suffolk/ Thurrock Traffic Counts (count data)

While we acknowledge that benchmark performance is important, we are not always comparing like for like, and are not 'formally validating' in the way we would for a traditional transport model. Data suitability is considered against each benchmark when considering how the model performs and are areas that can be refined as different questions are addressed by the model in later versions.

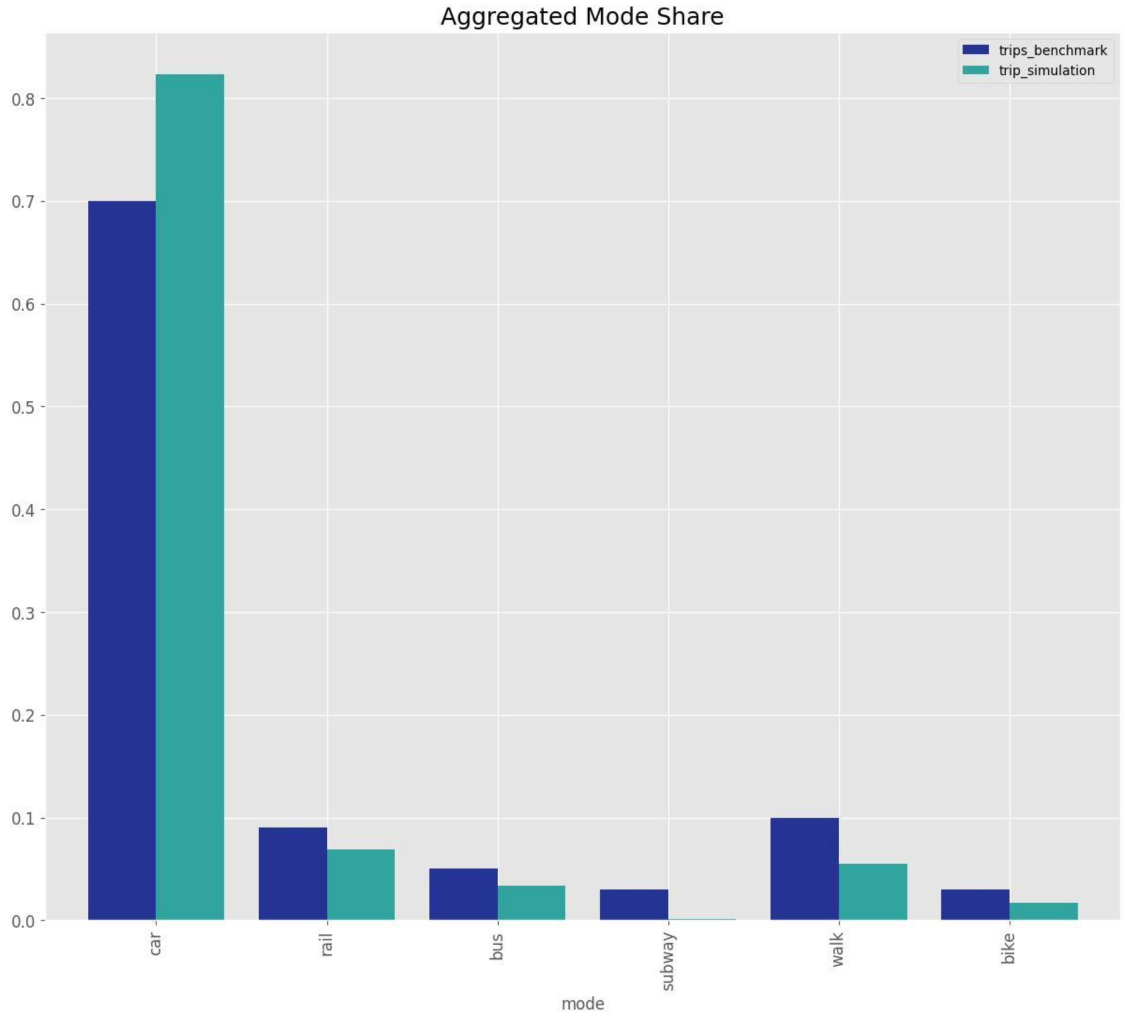


2019 Baseline benchmarking

Mode share against census travel to work census data

Travel to work (TTW) diary data was obtained from Office for National Statistics via Nomis, which provides 2011 estimates that classify residents aged 16 to 74 in England and Wales by their method of travel to work.

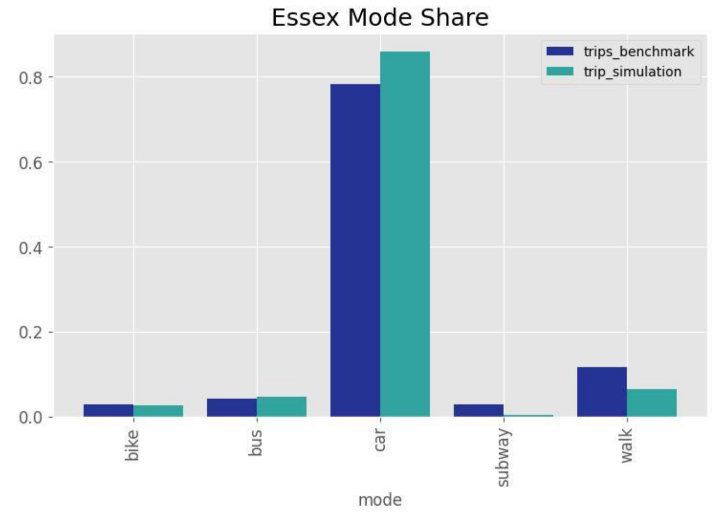
The data is provided at MSOA level, and for the purpose of this study, the data was cropped to include only those trips that originate, end or pass through the main study area boundary. The figure shows the aggregated mode share across the East region, which illustrates the model is overestimating car trips while underestimating walking and cycling.

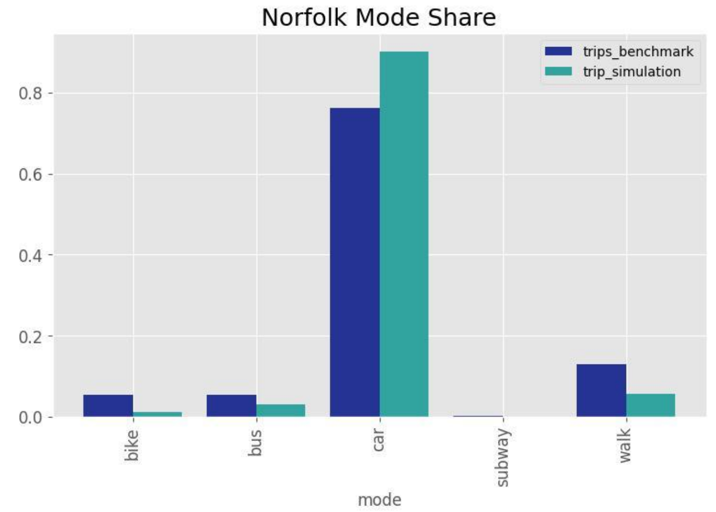


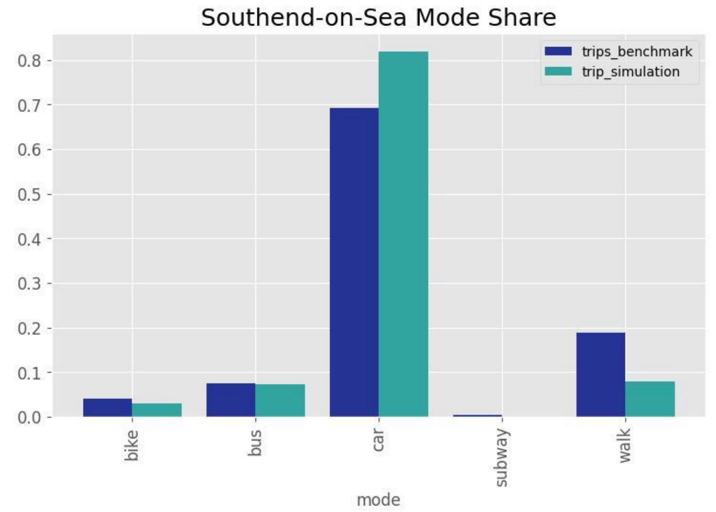
Top 2011 census TTW vs simulation

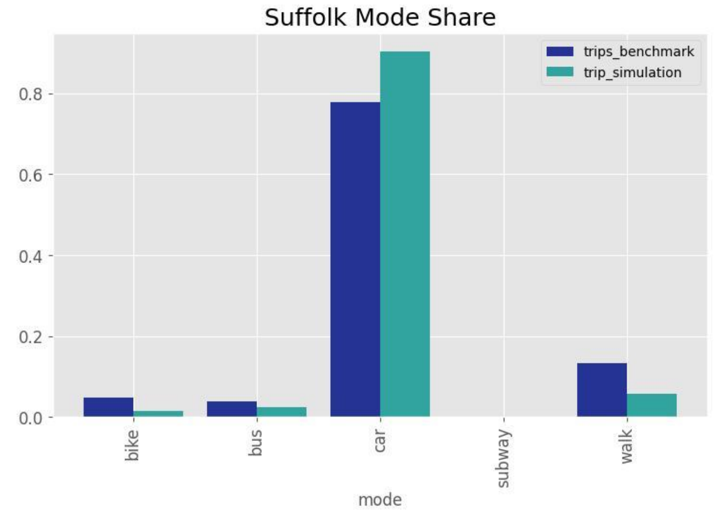
2019 Baseline benchmarking

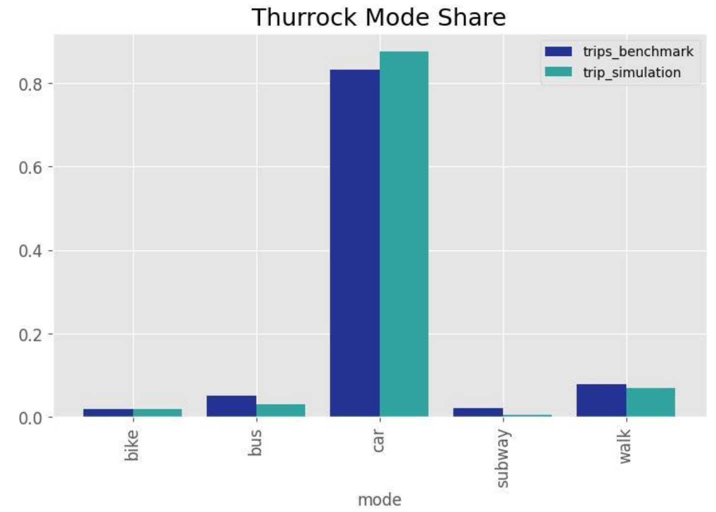
Travel To Work census data (mode share split by county)











These figures show mode share disaggregated by local authority area compared against 2011 census data. They show a similar pattern for most areas to the region wide data on the previous page, except for Thurrock with matches much better.

2019 Baseline benchmarking

Travel To Work census data (trip distance and duration – active modes)

The charts below show the simulation output trip distance and duration profiles compare against the weighted NTS profiles, split by mode for sustainable travel.

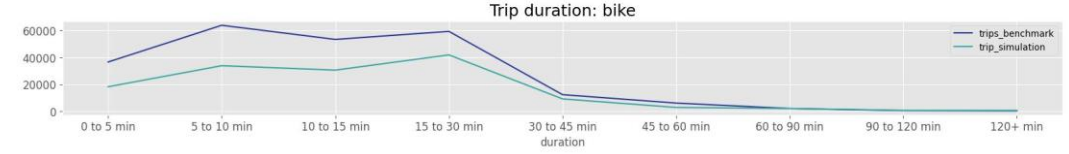
For bike, we can see the profile for trip distance generally matches well, with a peak in the 1-5km range, then a smooth tail down to very few trips longer than 25km. Overall, bike is slightly under the benchmark across all distances.

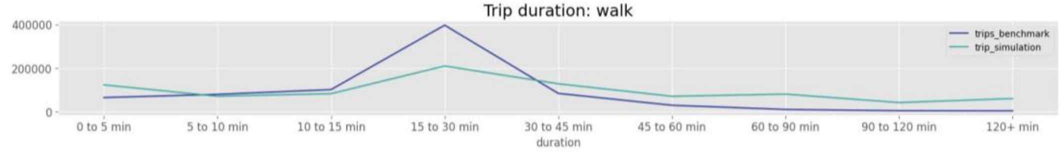
For bike trip duration, the model is also slightly under the benchmark, however again the profile across time intervals matches it well.

For walking, we can see the simulation has significantly more trips under 1km than the benchmark, however it should be noted that these are typically underestimated when conducting travel surveys. Beyond this, 1-5km matches very well with a steep tail to very few trips above 10km.

For walk trip duration, the profile generally matches well, but underrepresents the peak in the 15 to 30 minute range.

Overall these plots provide confidence that our trip representation and agent decision making for sustainable modes is in line with the available survey data. That said, there are opportunities to improve some of these in future iterations, especially around short distance walking trips.





2019 Baseline benchmarking

Travel To Work census data (trip distance and duration – public transport)

The charts below show the simulation output trip distance and duration profiles compare against the weighted NTS profiles, split by mode for public transport.

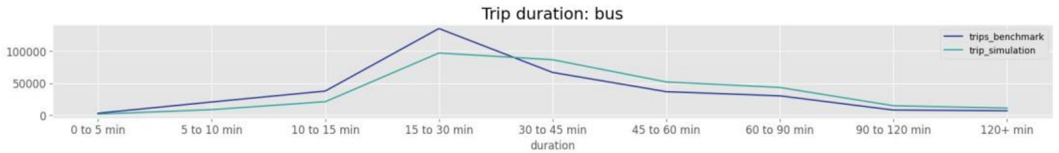
For bus, we can see the profile for trip distance generally matches well, with a peak in the 1-5km range, then a smooth tail down to very few trips longer than 50km. The simulation has slightly more trips in the longer distance bus between 10 and 50km.

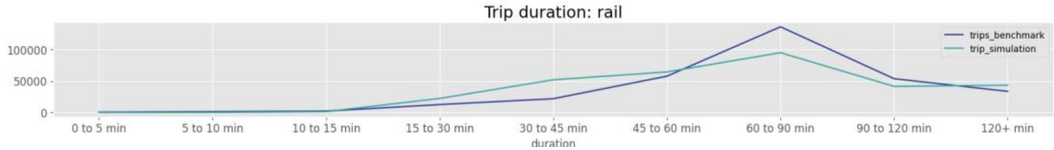
For bus trip duration, the model is replicates the benchmark exceptionally well, although slightly under for 15-30 minutes.

For rail, we can see the simulation has a similar profile to the benchmark, however the peak is at 10-25km rather than 25-50km. The low level of trips under 5km and over 100km are very well represented.

For rail trip duration, the profile generally matches exceptionally well, but underrepresents the peak in the 60 to 90 minute range. this is likely a result of the under-representation of 25-100km journeys.

Overall these plots provide confidence that our trip representation and agent decision making for public transport modes is in line with the available survey data. That said, there are opportunities to improve some of these in future iterations, especially around long distance rail trips.





2019 Baseline benchmarking

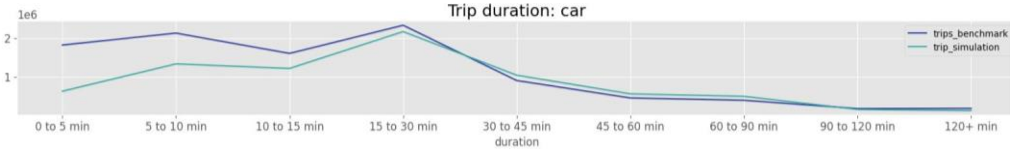
Travel To Work census data (trip distance and duration – car)

The charts below show the simulation output trip distance and duration profiles compare against the weighted NTS profiles, for car.

For car, we can see the profile for trip distance generally matches well, with a peak in the 1-5km range, then a second peak at 10-25km before a smooth tail down to very few trips longer than 100km. The simulation has overall has an exceptional fit to the benchmark data.

For car trip duration, the model is replicates the benchmark well for journeys of 10 minutes or more. For shorter duration car trips under 10 minutes the model is noticeable lower than the benchmark. Given short distance trip numbers have a better match, it is considered this is a result of short distance trips taking longer in the model and could be a result of low speed on minor residential streets. Further iterations of the model can consider this could be improved.

Overall these plots on this page and previous two pages provide confidence that our trip representation and agent decision making all modes is in line with the available survey data. That said, there are opportunities to improve some of these in future iterations, especially around long distance rail trips, short trip duration car trips and short distance walking trips.



2019 Baseline benchmarking

SERTM Traffic Flow Data

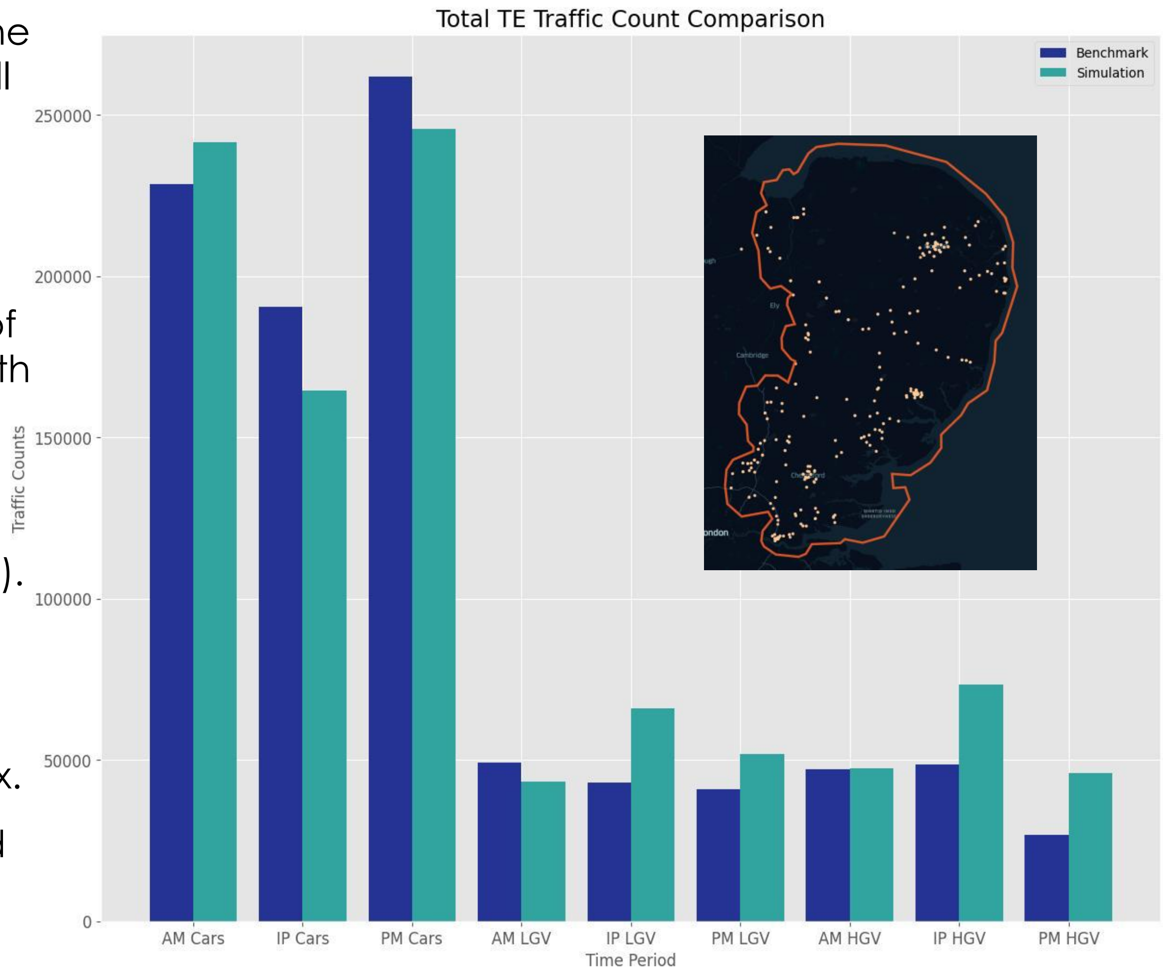
The inset map shows the traffic counter locations extracted from the South East Regional Transport Model (SERTM). This represents the full final screenline calibration and validation data set for the model. Each counter was matched with an appropriate link in the modelled network, such that traffic volumes could be compared.

SERTM contains observed count data taken from a variety of sources, covering both local and regional roads, and is reflective of pre-covid travel patterns, and should therefore be comparable with the baseline year.

The figure to the right compares the total volume of traffic in our simulation, compared with the observed SERTM data, split by vehicle type (car, LGV, and HGV) and time period (AM, IP and PM). The simulation can look at hourly flows, but SERTM aggregates to these time periods so the comparison is for 0700-100(AM), 1000-1600(IP) and 1600-1900(PM).

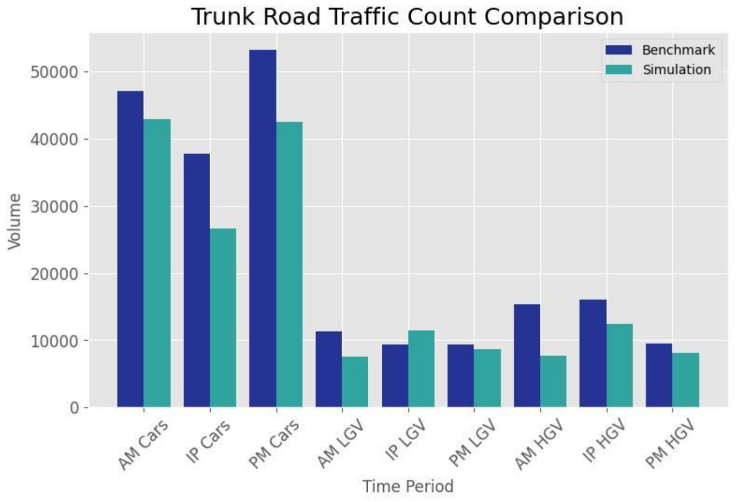
Detailed data output by screenline is provided within the appendix.

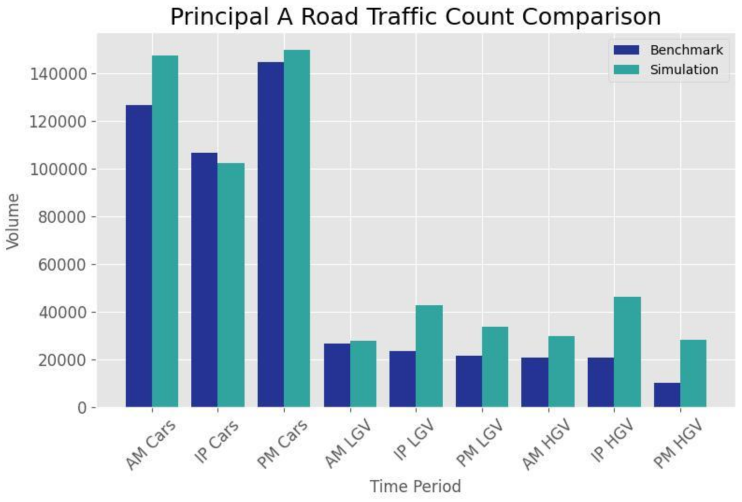
The chart shows that for cars and LGV the observed and modelled match well, and that combined would perform even better. The differences could be a result of difficulties in observed data differentiating between cars and light good vehicles.

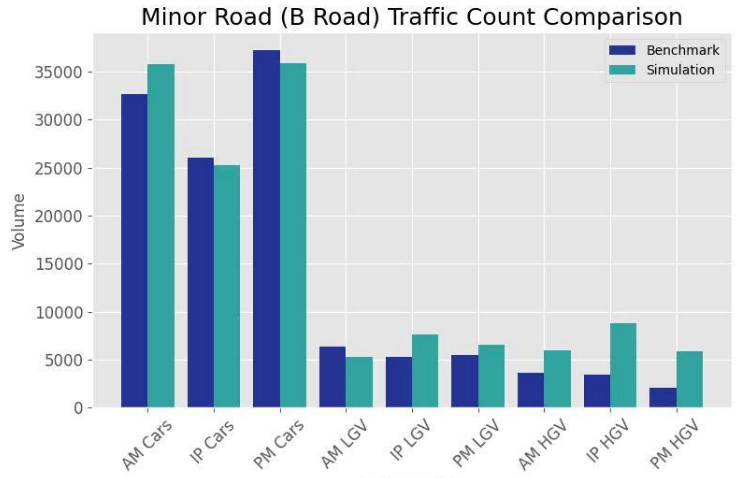


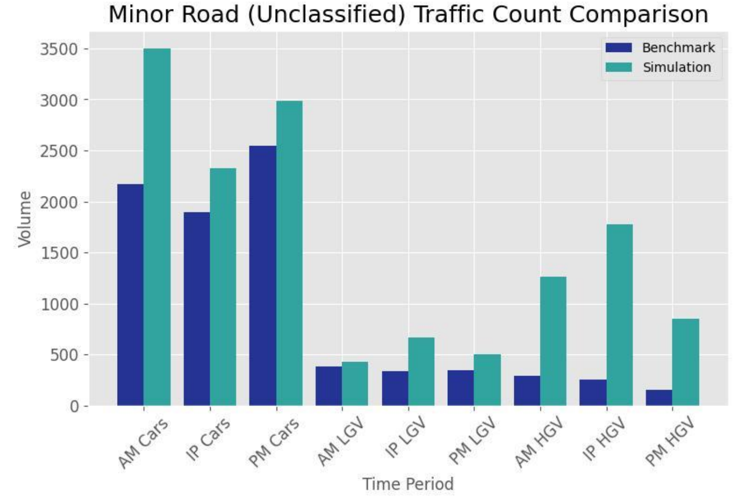
2019 Baseline benchmarking

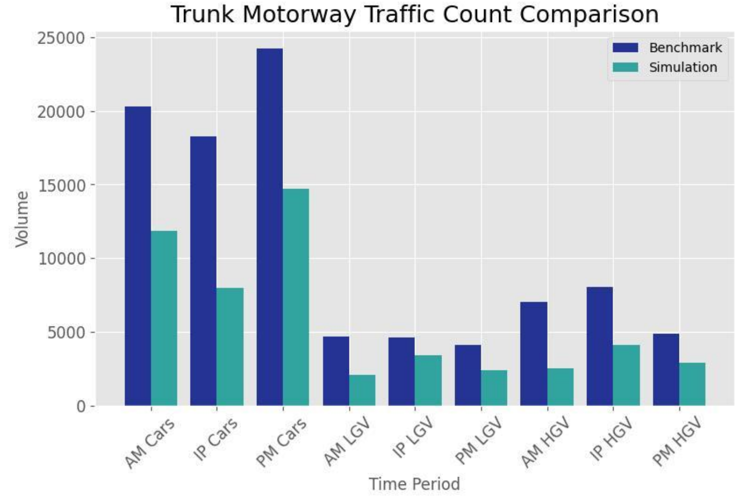
SERTM Traffic Flow Data (traffic volumes split by road type)











The figures on this page provide greater disaggregation of the SERTM2 data by road type to help identify any model biases.

The largest differences can be seen on the motorway links. A further review of this data has shown that the difference are driven by the SRN network on the edge of the model area, especially the M25. This is because the way the population in the model is built we do not have full demand for through trips on some of these links. For minor road HGV trips, this is a result of facility locations that will be reviewed in the next iteration of the model.

2019 Baseline benchmarking

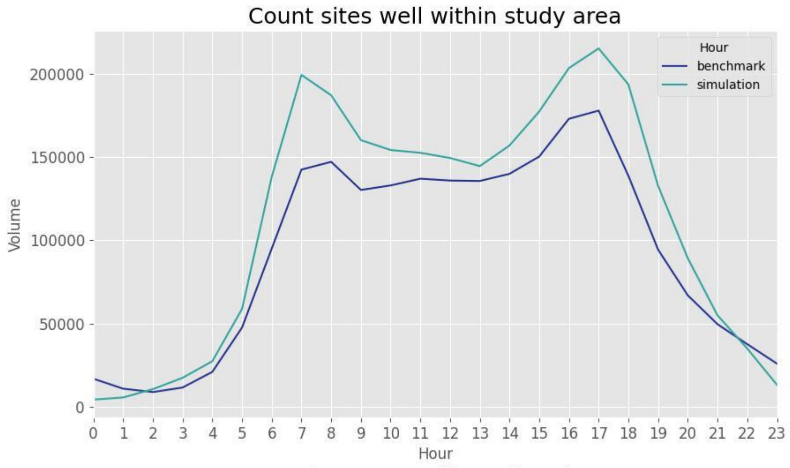
WebTRIS Traffic Flow Data

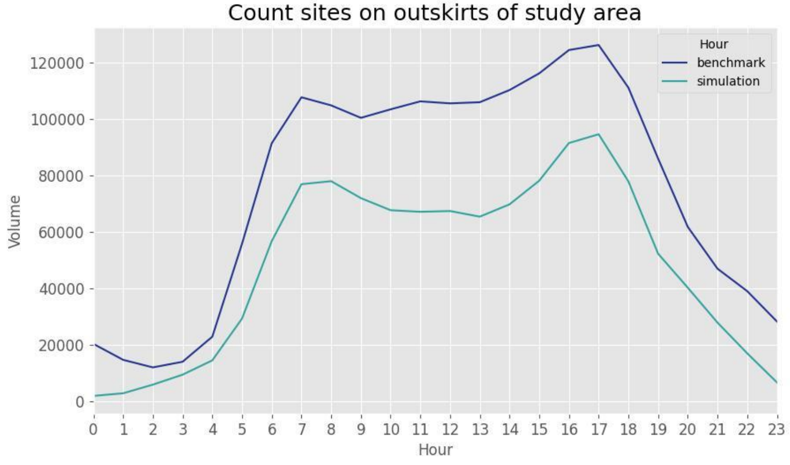
The WebTRIS Traffic Flow API was used to extract traffic count data recorded by Highways England for the Strategic Road Network (SRN) links within the main study area.

Average hourly counts were calculated for all weekdays (excluding bank holidays and school holidays) between April and June 2016 that had a full day of valid data. This time period was chosen to give representative pre-Covid traffic flows, and also to align with the traffic count data provided by Suffolk CC (see next page).

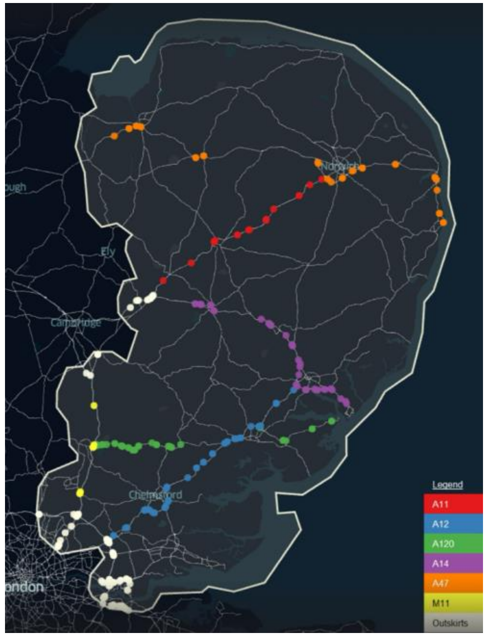
The figures to the right show the total 24-hour traffic volume profile for the observed WebTRIS data compared to the simulation volumes. Outputs from 2016 have not been scaled to reflect our 2019 base year, given at this point we are benchmarking rather than validating the model. This explains why sites within the study area are matching the profile well but have higher total volumes in the simulation.

For sites on the outskirts of the model, the simulation is typically underestimating demand as the population within the model does not generate all the through trips on the buffer area of the network, especially on and inside the M25.





WebTRIS count locations used for this study, categorised by corridor



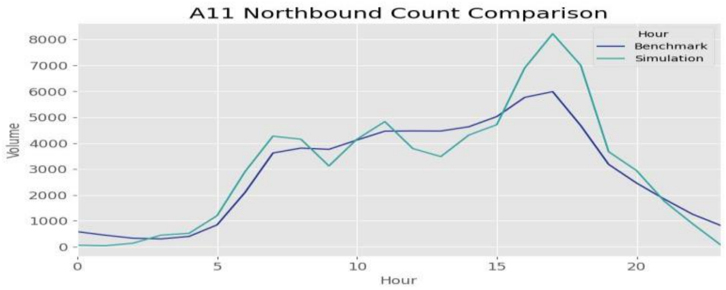
2019 Baseline benchmarking

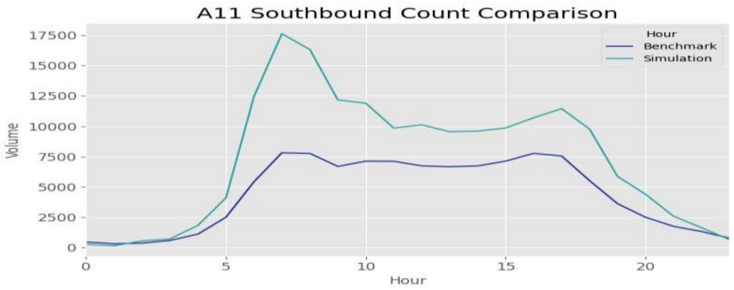
WebTRIS Traffic Flow Data (split by corridor)

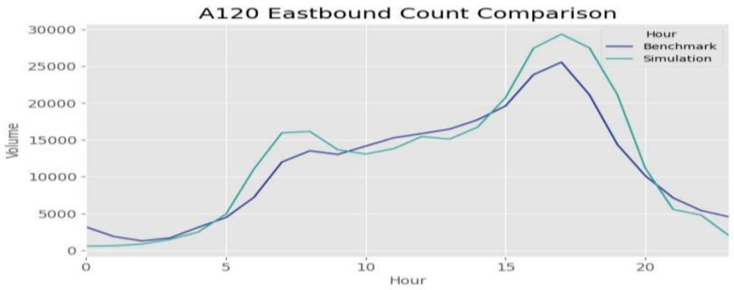
The following figures below show the results disaggregated by corridor (this shows a selection of corridors). These all represent corridors well within the study area, where we expect the simulation to perform better.

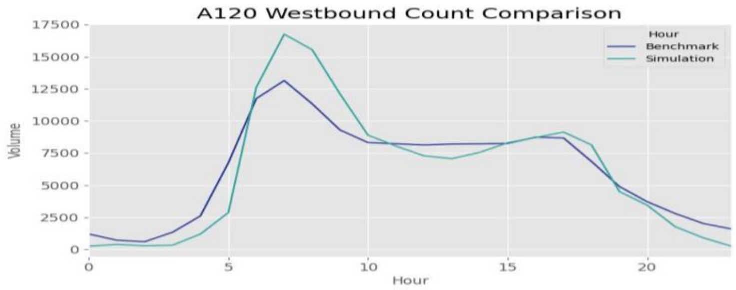
For the majority of corridors the simulation represents observed demand well, although a slightly higher peak in the model for A11 and A12 northbound. The A120 provides an excellent level of performance in both directions throughout the day.

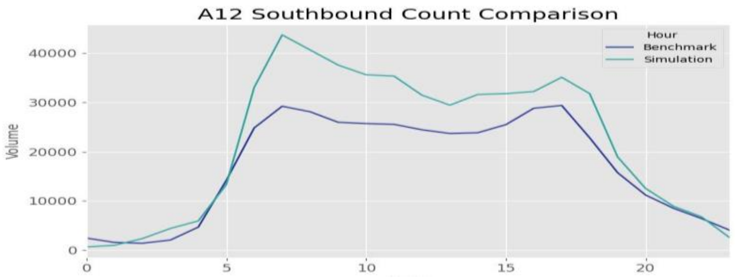
For the A11 and A12 southbound there are some more major difference and inconsistences in tidal flow data both in the observed and modelled values. Further investigation into the performance of these corridors will be undertaken in later versions of the model.

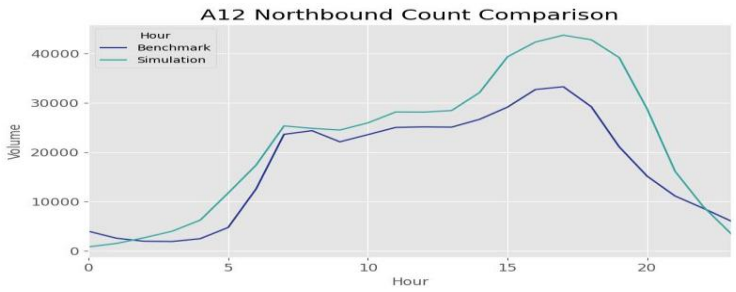












2019 Baseline benchmarking

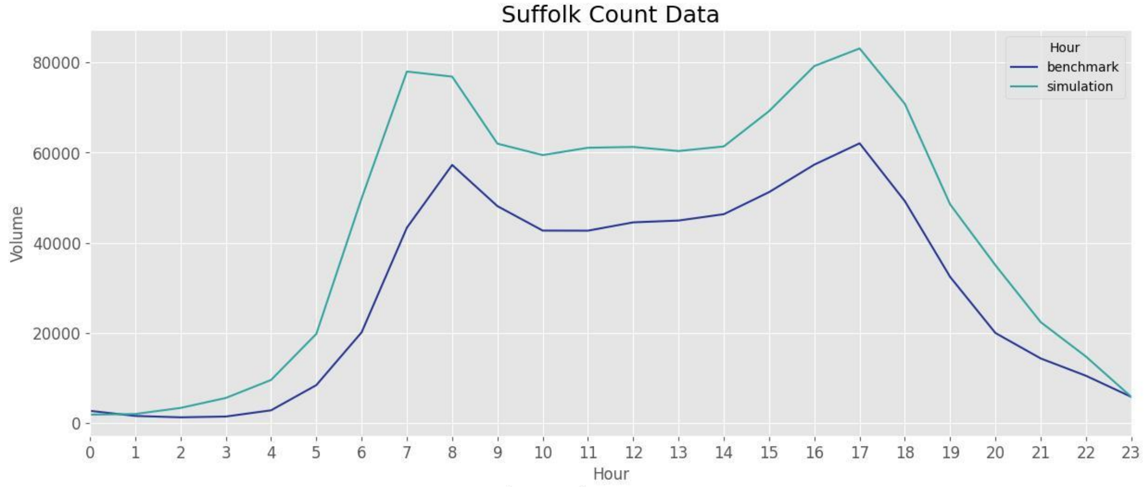
Suffolk / Thurrock Data

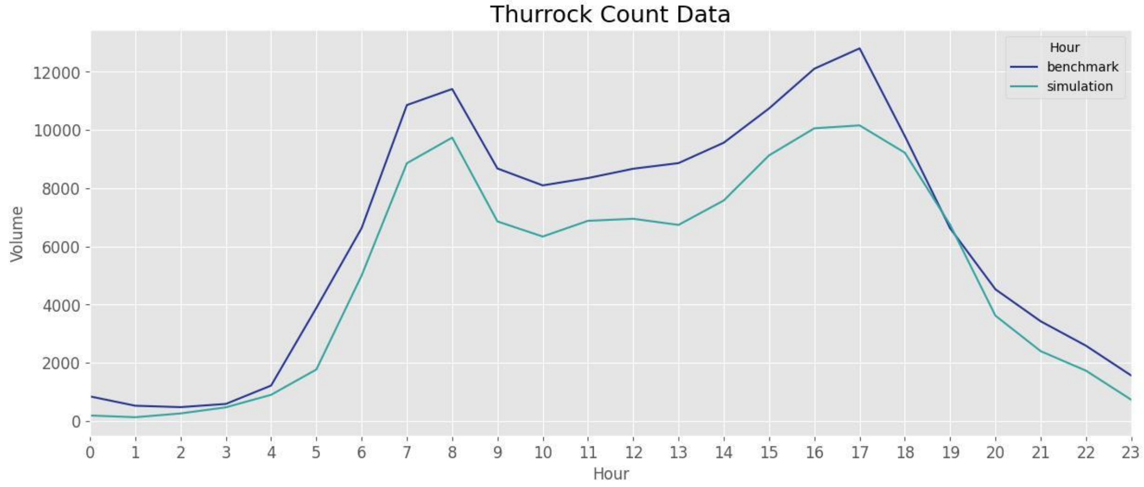
To compare simulation traffic flows outside of the SRN with observed data, count data was provided by Suffolk and Thurrock councils. This is the most detailed observed data that we have available as it gives individual hourly breakdowns.

Suffolk data covered the period April to June 2016, whilst Thurrock data covered the period June to August 2019. Crucially, both datasets represent pre-pandemic traffic flows. Again, we are trying to demonstrate that the model is replicating profiles throughout the day as well as volumes.

Similarly to the WebTRIS data, this was converted into average weekday hourly counts and compared to the simulation traffic flows for equivalent links on the network. Outputs from 2016 have not been scaled to reflect our 2019 base year, given at this point we are benchmarking rather than validating the model. This would explain why for Suffolk the model is generally over the benchmark data.

The daily profiles match very well, but there is some variation in overall levels of demand. As the model matures, more detail of the specific locations of count points, impact of freight demand, and making sure our simulated day is consistent with the benchmark data collection will be important.





2019 Baseline benchmarking

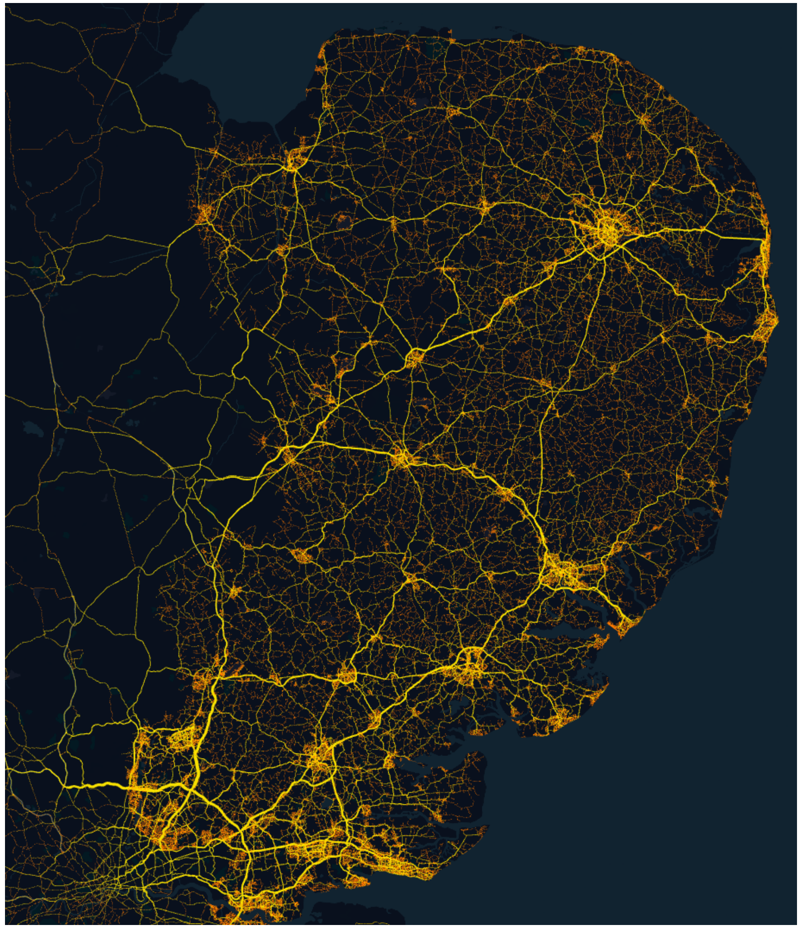
Summary

The model is performing well, and displaying realistic travel behaviour based on our benchmarking. The model displays similar profiles of traffic when compared to a variety of datasets and performs well across modes in terms of trip length and time distribution. There are a number of areas for future improvement and this should be considered when looking at scenarios and questions that can be currently answered. At this stage we are looking at strategic questions around decarbonisation, not looking at schemes or producing formal forecasts.

It is worth reiterating that this model is the result of four months of development, and is at the high end of the 'alpha' level of maturity. This means that we are confident that we can use this model to look at strategic policy questions including at a regional and more local level. The key factors within the model are about agent behaviour, the decisions they are making and their responses to changes in scenarios. A range of benchmarks have been presented to provide confidence in the ability of the model to do this.

There are areas that we would like to further develop and refine in the model. However, these refinements aren't required for the model to be useful. As part of future scenario testing we would expect the maturity of the model to improve, with new iterations of the network and population being built as part of studies that require additional detail.

There is an ongoing challenge with getting better data, both in terms of post-pandemic benchmarks, and in improving the freight demand model.



9am hourly traffic flow

2040 Baseline

- **Development Overview**
- Model performance

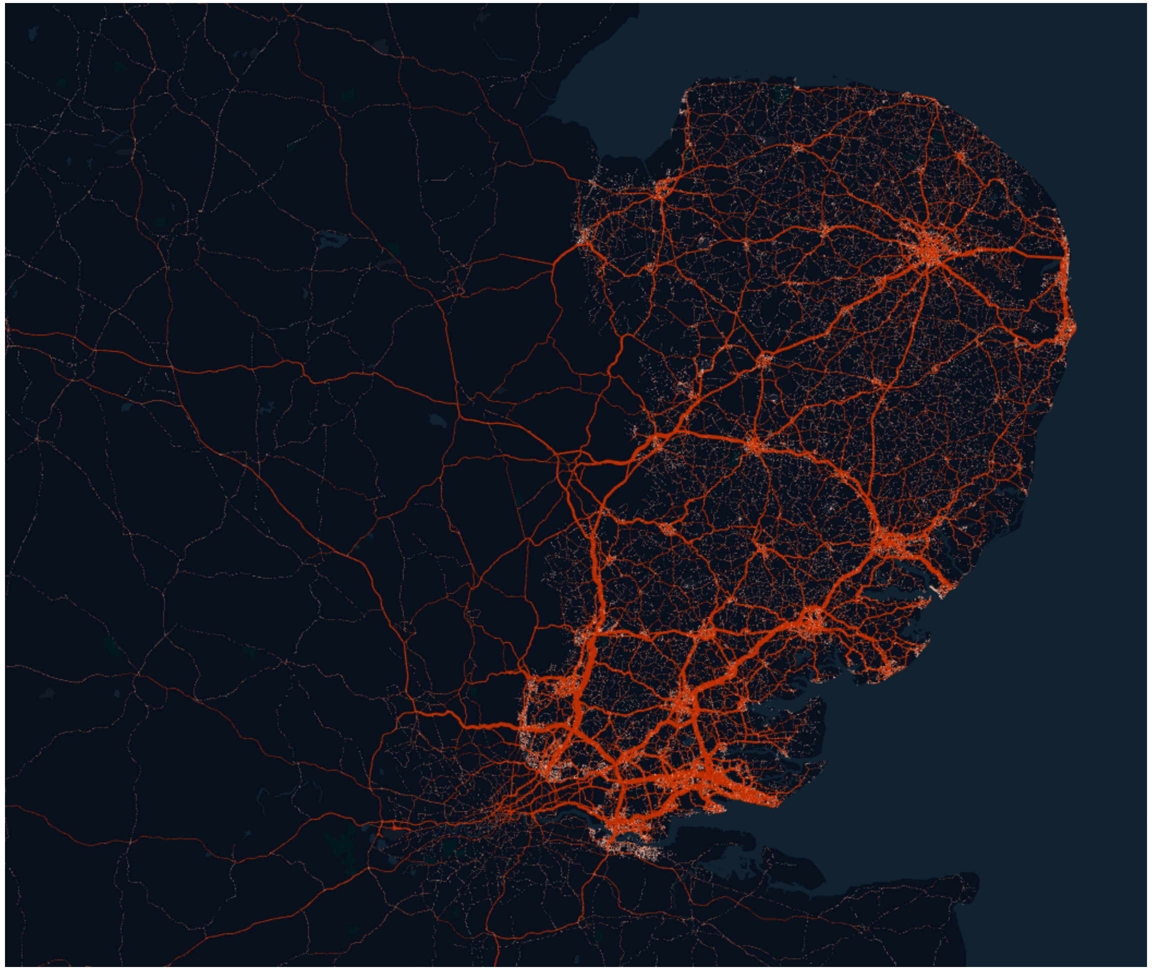
2040 Baseline overview

The 2040 baseline reflects a likely case for 2040

When looking at future year model, we need to account for a range of changes to the 2019 baseline. The same parameters as the 2019 simulation are retained for consistency and we cannot benchmark the 2040 simulation given there is no observed data to compare against.

We have made the following changes to the model:

- Updated the transport network
- Updated population and demographics
- Included a proportion of people in office-based employment working from home
- Updated the vehicle fleet, including electric vehicles, and improvements in emission standards for ICE vehicles
- Updated the cost of private vehicles, primarily to reflect expected cheaper EV running costs



Total car volumes

2040 Baseline network

Road network

The future year network for 2040 includes a number of changes from the 2019 baseline, both to the physical road infrastructure as well as to public transport infrastructure and schedule.

For the physical road infrastructure changes, we reviewed transport development plans for each of the Councils in the Transport East area, and we selected new schemes that are confirmed, and updated the network to reflect these changes.

For each of these schemes, we obtained drawings, analysed the existing baseline network in that area and decided how best to represent the change, e.g. between which nodes will we create new links, which links change capacity etc. The majority of schemes in the plans were upgrades to specific junctions, and were therefore too detailed to impact the model's network.

The list of schemes that were considered but not included (including why they weren't included) can be found in the appendix

The following changes to the road network we implemented in the 2040 network compared to baseline:

Bridges:

- Gull Wing, bridge for Lowestoft, Suffolk
- Great Yarmouth Third River Crossing, Norfolk

Road links:

- Norwich Western link, Norfolk
- Long Stratton Bypass, Norfolk
- A120 to A133 Link Road, Essex
- A127/A130 Fairglen Interchange: new 'Southend Link Road', Essex
- Chelmsford North-East Bypass, Essex

Dualling:

- A12 dual carriageway at Woodbridge, Suffolk

2040 Baseline network

Public transport

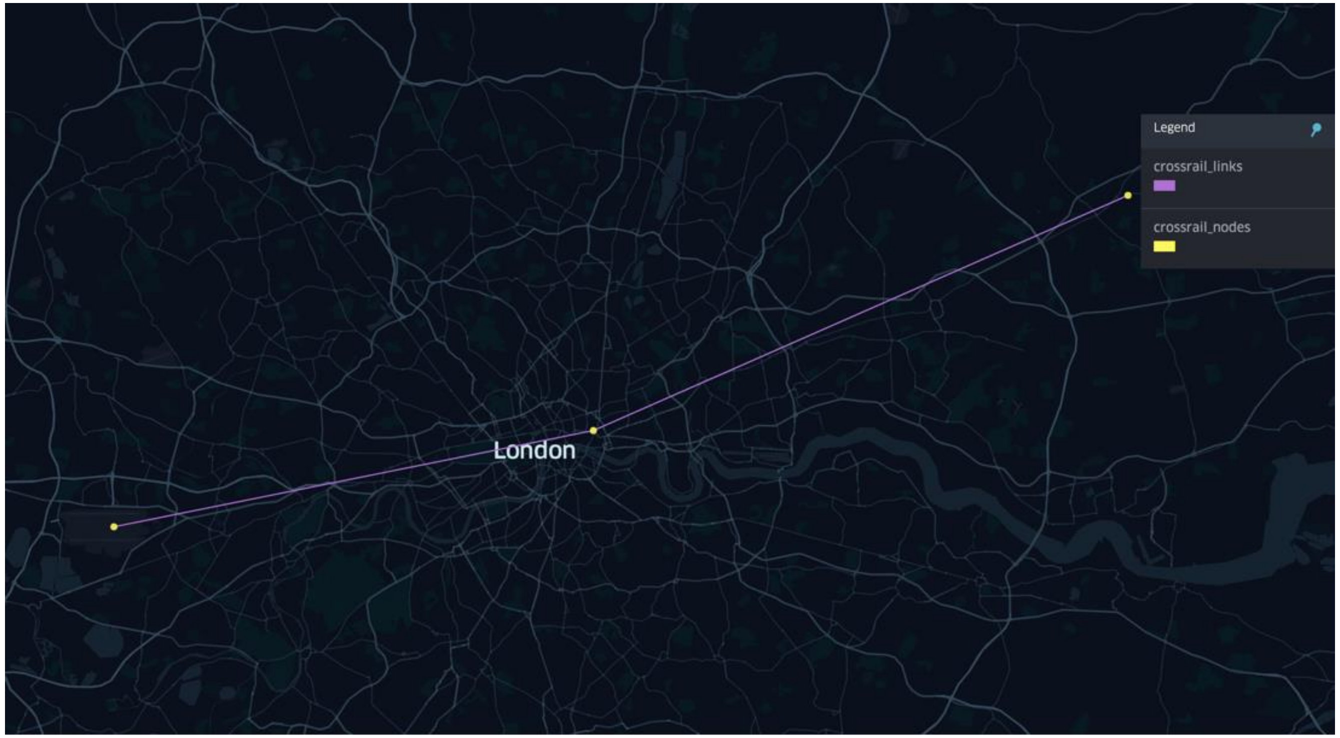
The only public transport infrastructure development that was chosen to be implemented for 2040 in the model is the Elizabeth Line (Crossrail).

As discussed on page 19, commuting demand to London is mapped to specific stations to remove the need to model the entirety of commuters' onward journeys (and therefore the full London transport network).

Therefore, we only include three stations in the future network, selected based on the destinations of agents' trips. These are:

- Heathrow (Terminals 2 and 3)
- Liverpool Street
- Shenfield

These were added in using our GeNet* tool, one of Arup's open source tools for working with MATSim networks.



Elizabeth Line services added to 2040 Network

*GeNet package: https://github.com/arup-group/genet
GeNet blog post: https://medium.com/arupcitymodelling/putting-transit-on-a-map-with-genet-11dd7bf835d7

2040 Baseline population

Forecasting 2040 demographics

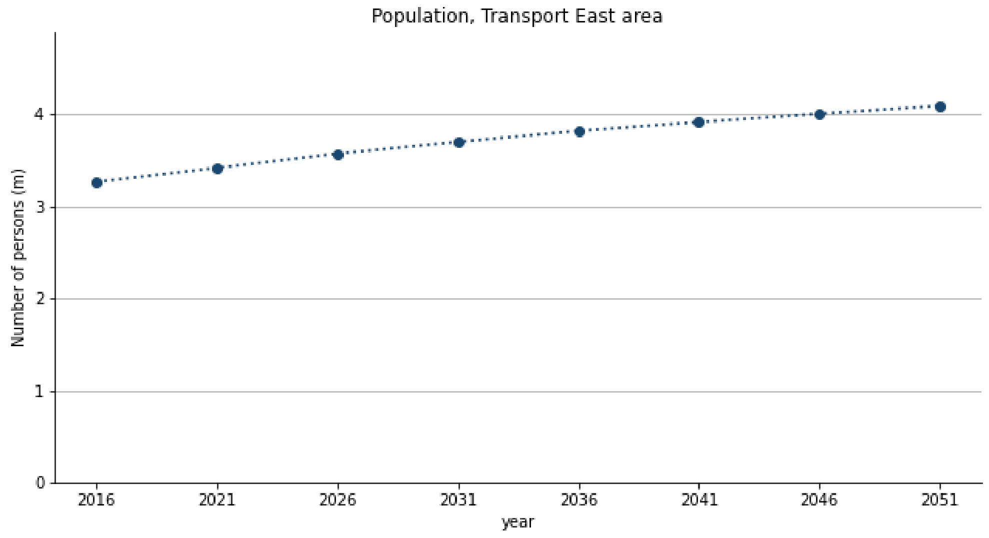
A new population was generated for our 2040 baseline. This allowed us to capture the detail from other forecasts, rather than trying to transform our 2019 population into a 2040 one (with associated long term choice modelling).

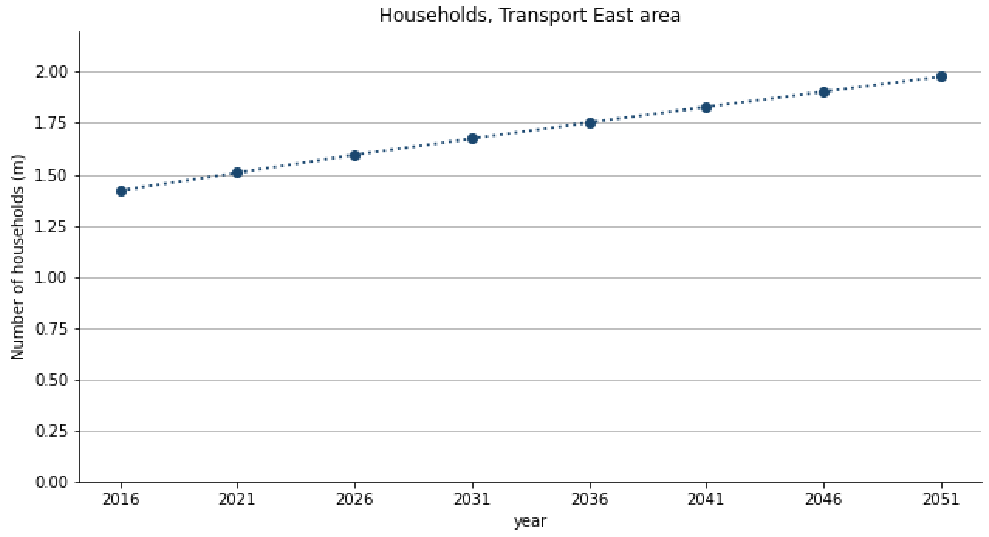
The forecasting process we used captures expected shifts in the characteristics and growth of TE's population, in line with established projection data (ONS and NTEM 7.2).

A "reweighting" exercise on the NTS data applies zone-level controls on attributes such as the number of persons, number of households, household structure, gender, age, and car availability.

The 2040 population encompasses trends such as population ageing, higher car ownership, lower household sizes, and electric vehicle take-up.

The charts show the expected growth in both population and households within the study area that result from this process, along with a decrease in household size.



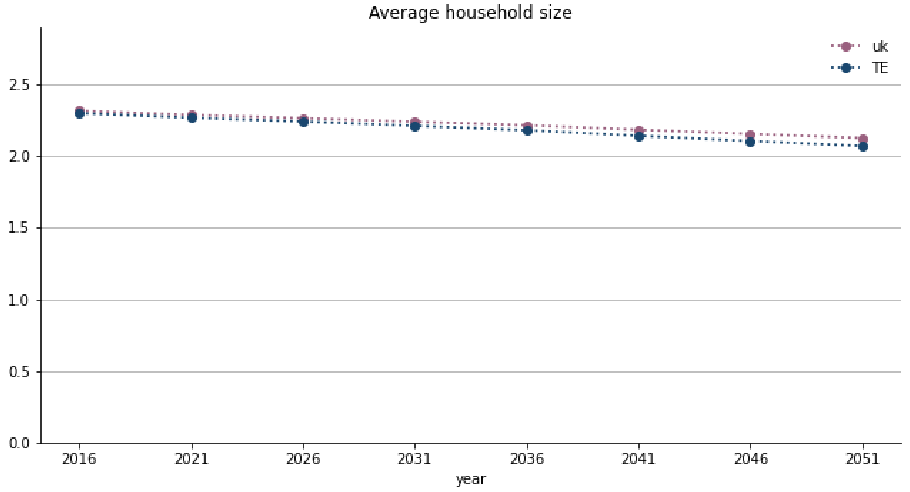


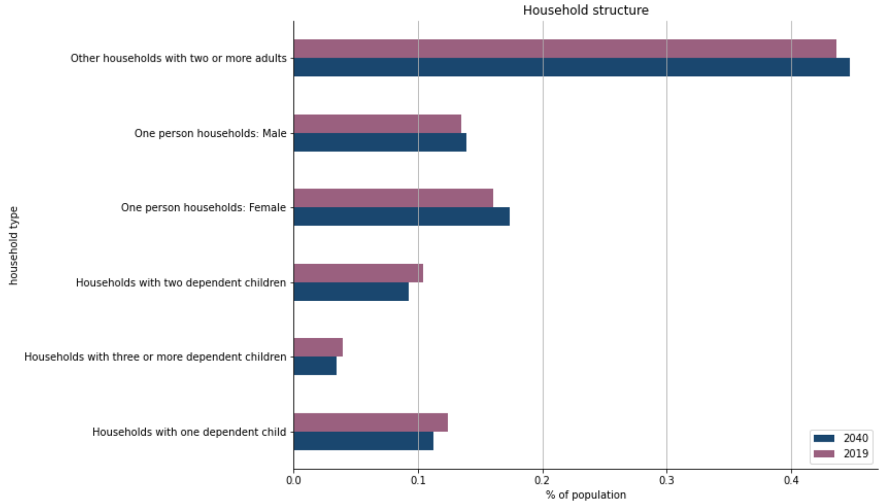
2040 Baseline population

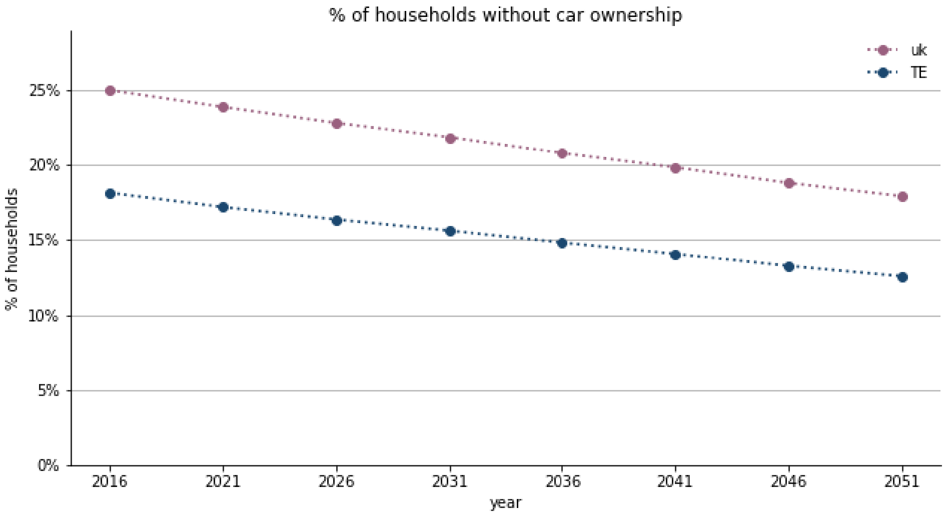
Household characteristics

Households throughout the UK are decreasing in size, and more households have access to a car. However, this isn't a consistent or flat trend across the entirety of the UK. For our forecasts, we have made sure to use data that is based on the specific Transport East region.

This means that our 2040 population respects the unique demographic challenges that exist within the region, and therefore we can be confident in the validity of our future population.







2040 Baseline population

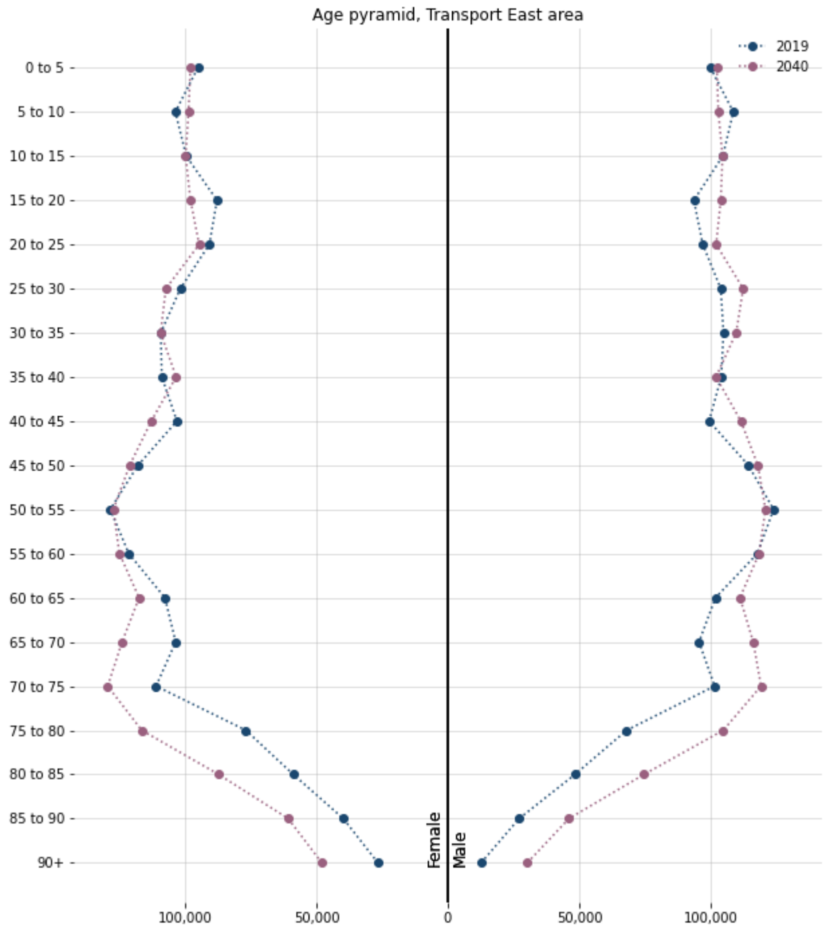
Population growth

The Figure shows that the growth in population for the Transport East region is disproportionately weighted to older demographics and increases over time.

With the agent based approach, our model will not just reflect this growth in population, but also that these growth demographics will have very different activity plans and behaviours than younger people. We would expect that these older groups would also have lower rates of car access, and be more dependent on public transport.

The final task was to allocate this growth in population spatially, plots for both population and household growth can be found on the next page.

This means that the 2040 population has been generated and distributed across the region in a way that is consistent with demographic and spatial changes expected. With these changes in the region, we would expect some markedly different travel behaviour to be evident in our 2040 future model.



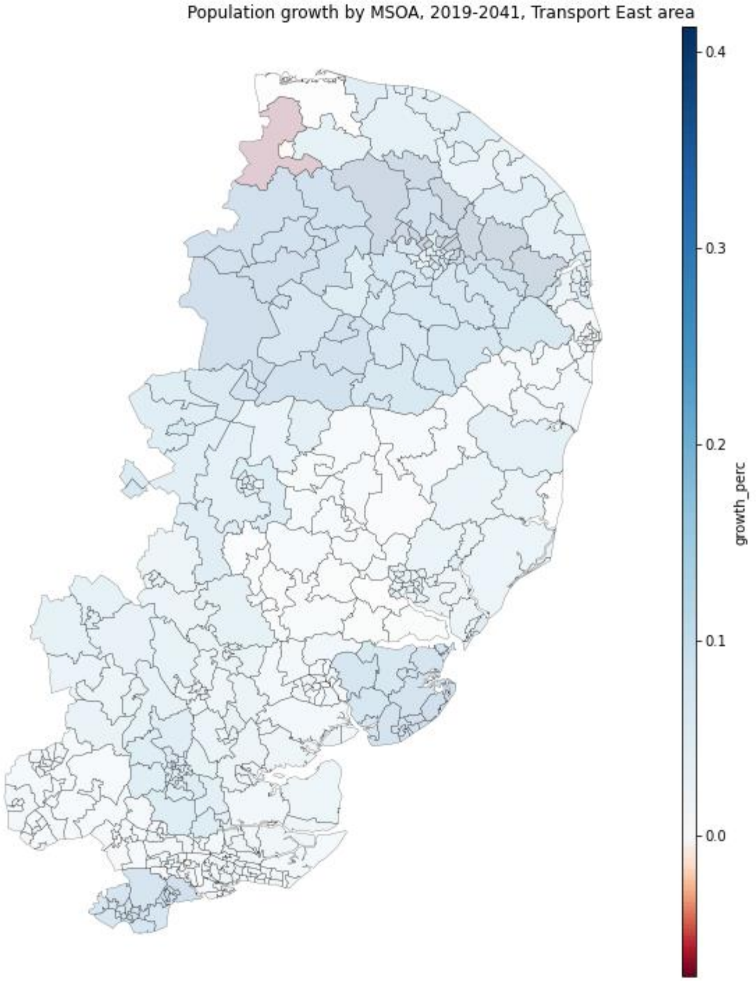
2040 Baseline population

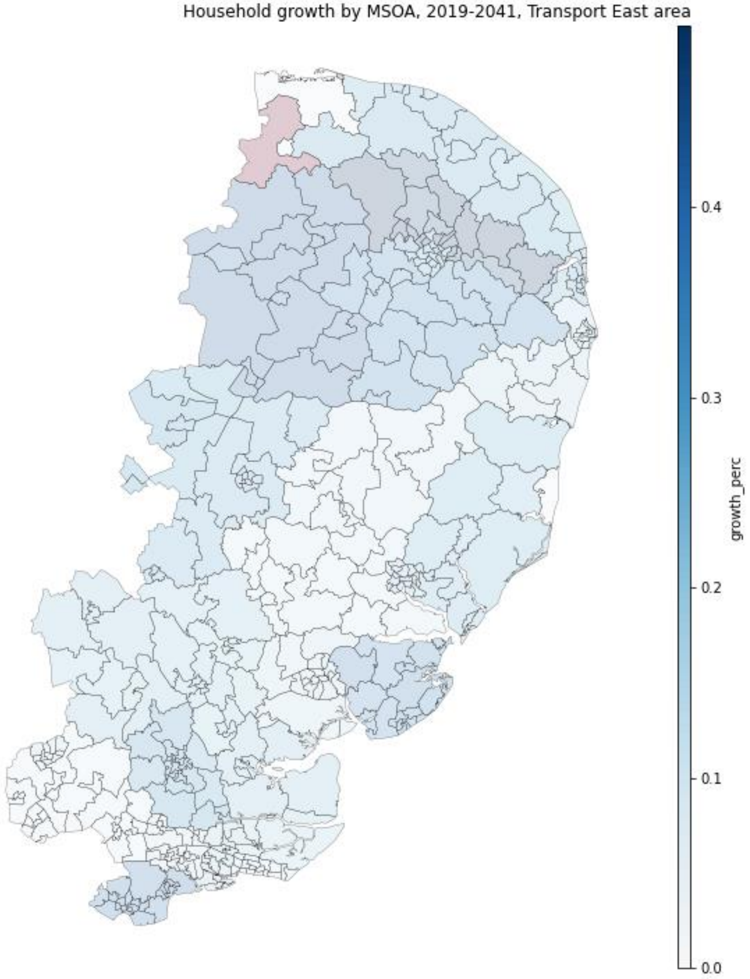
Population growth – spatial distribution

Growth in the region is focused on the MSOAs around key towns within the region, with particular hotspots around Colchester, Chelmsford, and Norwich. From a county perspective, there is more growth in Norfolk.

There is a decrease in population forecast around King's Lynn, though this may be worth revisiting at a later date as the MSOA is on the edge of the study zone.

We are happy that this future population both captures relevant future forecasts from ONS and DfT, and has been expanded with information relevant to our future modelled year.





2040 Baseline population

Changes to behaviour and EV uptake

We have seen over recent years that large scale behavioural changes are likely to be a feature of our society as we go forward. Assuming that people in the future will behave in the same way as people do today is fundamentally wrong. This poses a challenge with modelling as we don't have data to represent these changes. We have embodied different changes into our 2040 population using a range of methods and assumptions.

Working from Home: We believe that working from home will be a substantial and long lasting change to people's travel behaviours. Our agent population has an employment category (from NTS). We assumed a 40% working from home rate (two days a week full time) for agents tagged to "managerial and technical", "professional", and "skilled non-manual" occupations. We then used our PAM tool to assign 40% of agents in these categories to have work activities at the same locations as their homes, and gave the agents a 'wfh' tag. This resulted in 76,498 work trips being relocated across the whole population (421,455 agents).

Driving costs: Agents with vehicles are divided into two sub-populations, those tagged as 'EV' and those with traditional cars. This means that the groups can have different costs of car travel, and these costs were updated for the 2040 population based on the TAG Databook.

Vehicle fleet update: We have future projections for EV uptake in 2040, however, we needed to assign these to agents. We used existing NTS data on EV owners and TAG forecasts to model future uptake and assigned vehicles in line with the table below. For our carbon analysis, we also aged the existing vehicle fleet, assuming that future combustion engines would be more efficient than the current fleet.

mode	household income	2019 Baseline	2040 Baseline	2040 EV Double	2040 EV High
car	low	0.8%	25%	50%	79%
car	medium	0.8%	27%	54%	86%
car	high	1.4%	48%	95%	100%
lgv	N/A	0%	19%	38%	81%

Probability that a household with a car, has an EV (given income)

2040 Baseline

- Development Overview
- **Model performance**

ARUP

TRANSPORTEAST

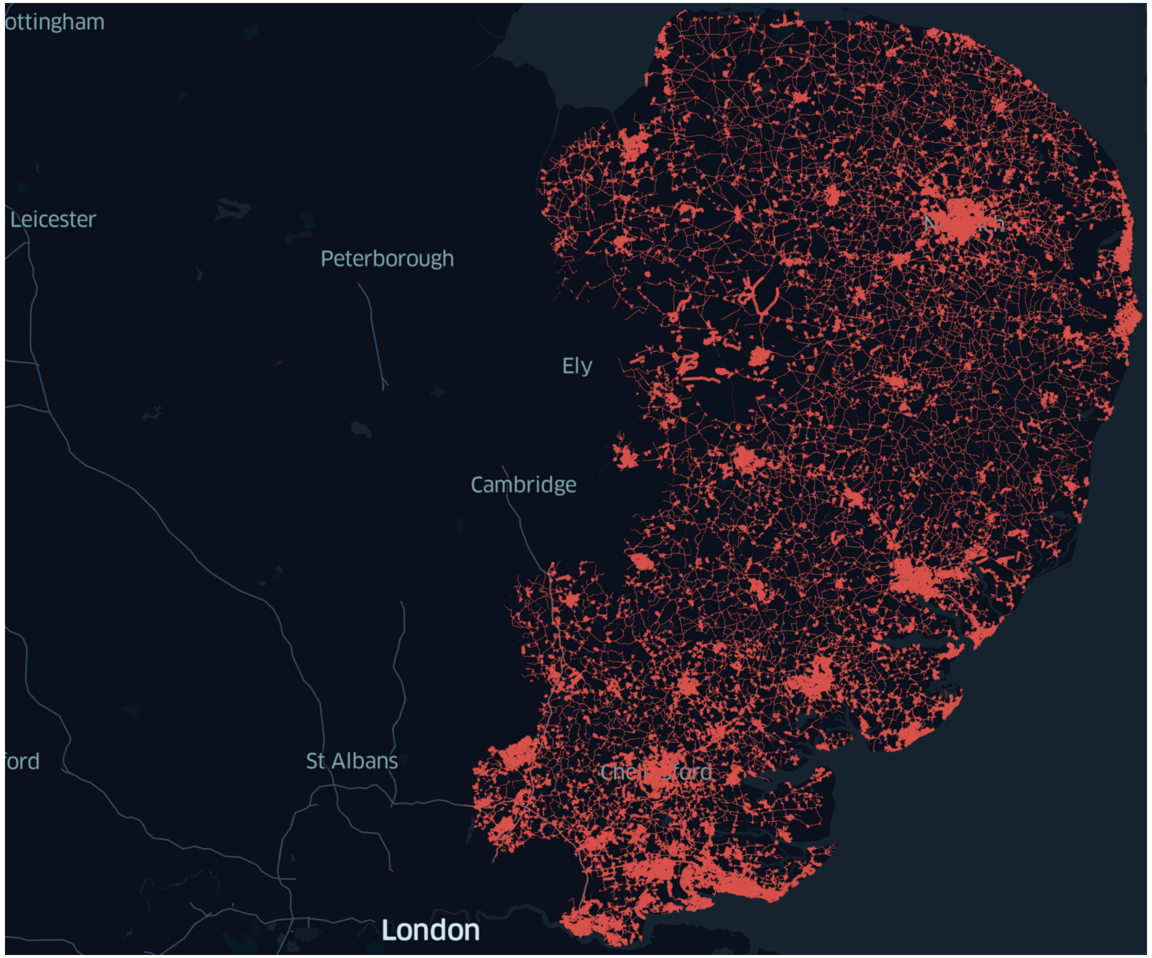
2040 baseline – Model Performance

A baseline we can use to test forecast year scenarios

The 2040 Baseline model is important because it provides a reference point for comparison of future year scenarios. While 2040 scenarios can be compared against the 2019 baseline, there are differences within supply and demand that do not form part of the specific scenarios to be assessed.

This 2040 baseline therefore creates consistency between the behaviours in each of the simulations, which enables us to draw insights from comparative performance of the 2040 scenarios.

In this section we describe how the 2040 baseline model preforms, i.e. what we see from the outputs at the end of the simulation run. We see changes to the model performance and the simulation that are in line with our expectations based on the changes to the input network and population.



2040 Baseline carbon emissions per vehicle km

2040 Baseline Network Performance

Trip statistics and mode shares

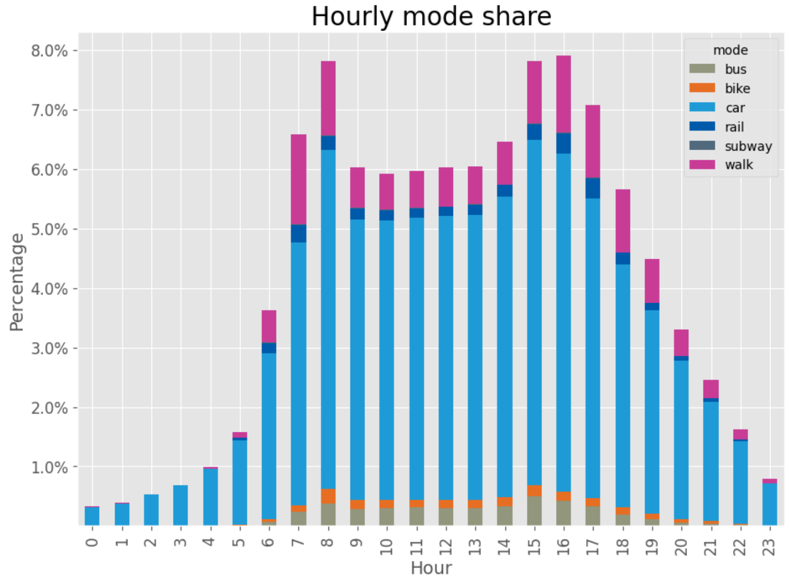
The table to the right shows the travel statistics by different modes across the full day in comparison with 2019 baseline. Since the population has increased, there is an overall increase in trips observed across all modes.

The figure to the right shows the hourly mode share distribution for the 2040 baseline scenario. The overall pattern is consistent with 2019 baseline with a level of mode shifting.

Private car trips are still dominant force among all modes listed, with an increase of more than 1.3 million trips and 25 million km travelled.

The following page compares the absolute hourly trip profiles between the 2019 and 2040 baseline simulations, split my mode. The increase in trips is most notably during the AM and PM peaks.

Mode	2040 Trips	2040 Travel Time	2040 total distance
HGV	1,768,080	62,566,441	32,831,105
LGV	1,645,650	62,827,037	37,770,409
Car	7,044,660	209,706,880	140,813,439
Bike	291,990	5,043,764	1,251,338
Bus	574,230	27,118,655	6,226,004
Rail	439,280	33,030,634	16,465,102
Subway	23,170	1,671,718	1,194,525
Walk	1,866,560	63,286,494	3,166,145
Total	**13,653,620**	**465,251,622**	**239,718,067**



2019 vs 2040 Baseline Comparison

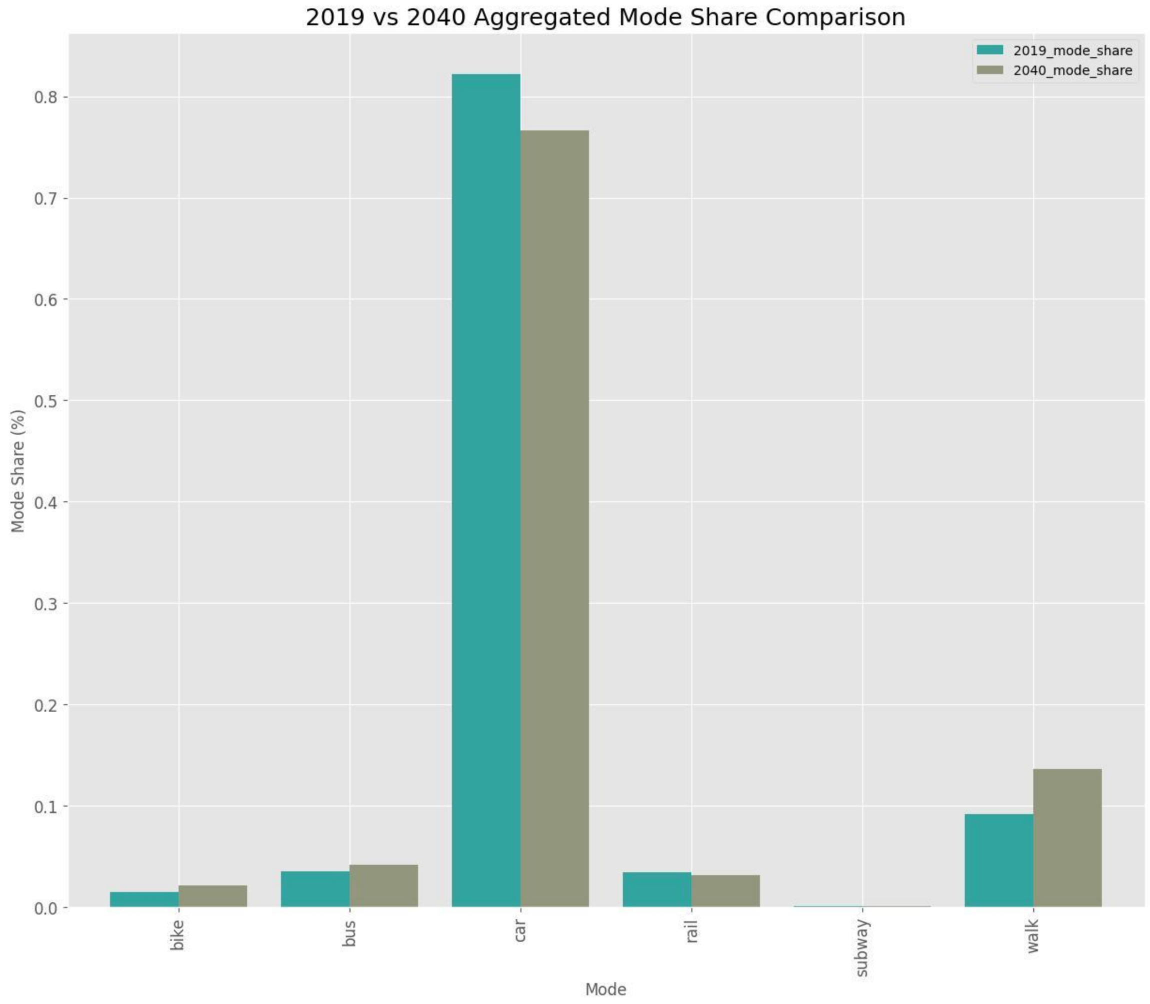
Aggregated mode share comparison

The figure to the right compares the mode share split aggregated across all simulation trips. As expected we can see a shift away from car trips (approximately 5%pt) towards bike, bus, subway and walking trips. The proportion of rail trips remains similar between the 2019 and 2040 baseline simulations.

This shift pattern is expected given the population and network changes made between these two simulations, as we have increased the demand placed on the network without significantly adding to its capacity. This growth in demand includes the trips removed as part of the working from home changes to trips.

The Elizabeth Line is classified as a subway in the model, which accounts for the increase in trips, though this is hard to see on the chart to the right given the very low mode share generated by trips into London on TfL services.

Essentially, we have growth across all modes, but more growth is going to non-car modes as the network is operating closer to maximum capacity in 2040.



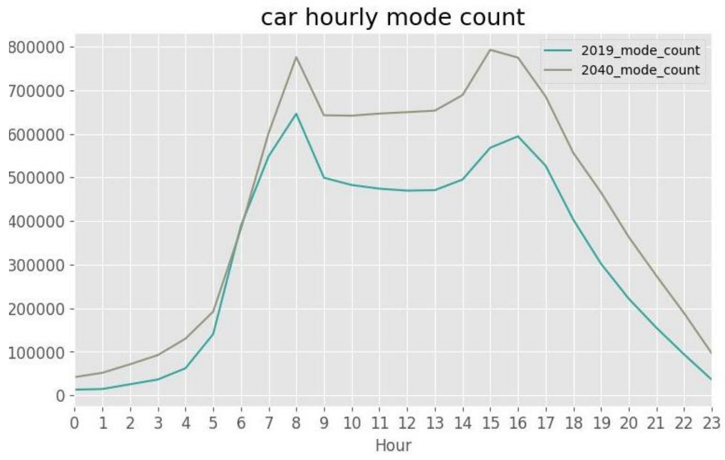
2019 vs 2040 Baseline Comparison

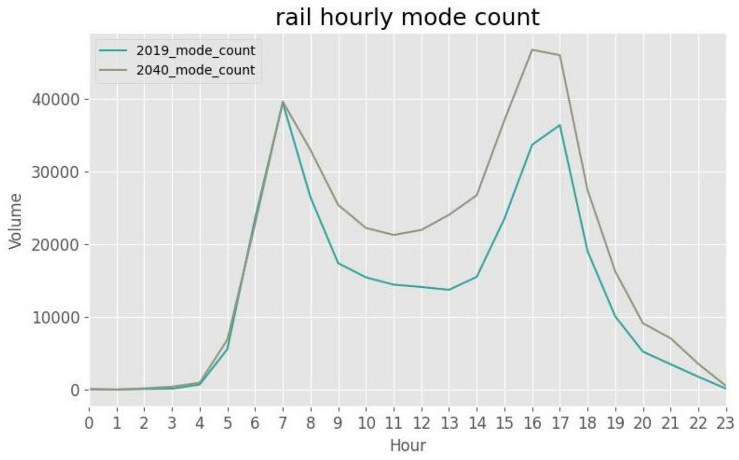
Hourly count comparison

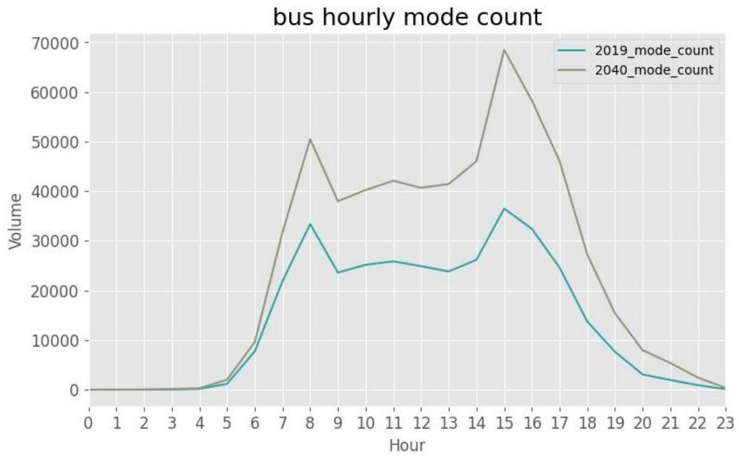
The first figure shows the growth in car traffic between the 2019 baseline and 2040 baseline and demonstrates it is not uniform across the day. Growth in the morning peak is quite small. This is likely caused by the aging (and working from home) population's reduction of activity types that have fixed opening times such as work and education. Most growth is later in the day, where there is more flexibility.

For rail we can see a similar pattern, although no growth in the morning peak hour. Further review of data indicates that this is in part due to the capacity of the rail network affecting when people choose to travel and by what mode. This also indicates more intra-regional trips being taken, as opposed to just commuting flows in and out of London.

Bus growth is strongly aligned to the time periods where buses are operational, with the most pronounced increase in the evening peak period.







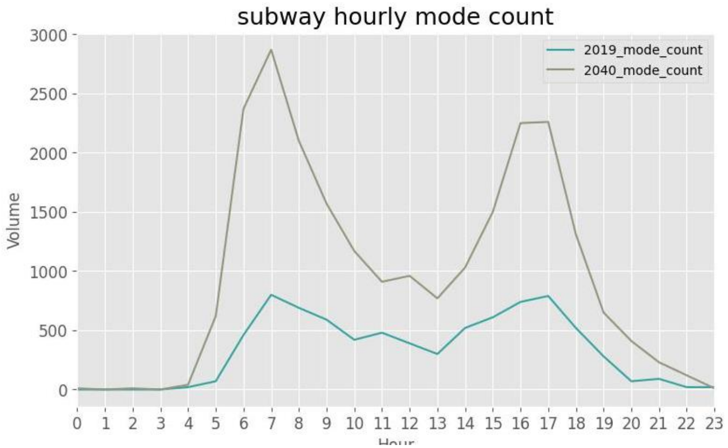
2019 vs 2040 Baseline Comparison

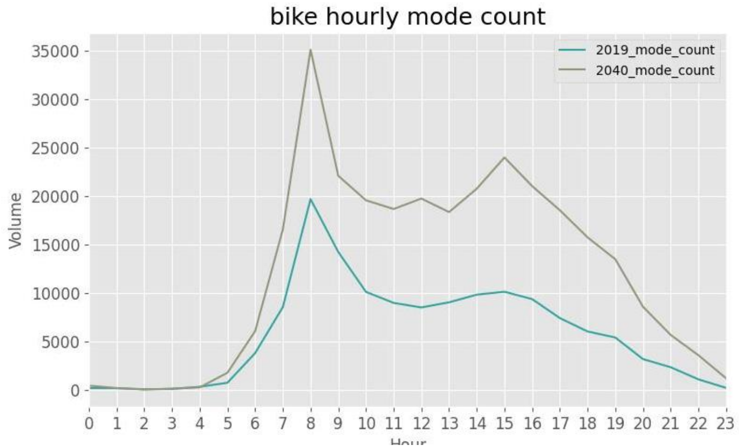
Hourly count comparison

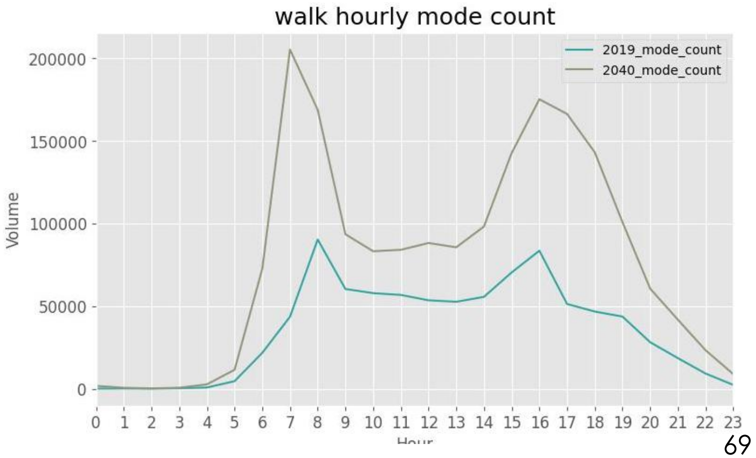
The first figure shows the growth in subway traffic between the 2019 baseline and 2040 baseline and demonstrates it is not uniform across the day. Growth is heavily focused in the morning and evening peak periods and is likely as a result of the inclusion of the Elizabeth Line within the 2040 forecasts making subway travel more attractive.

For bike, we see growth focused in the morning and evening peak period but also still substantial increases through the middle of the day. The disproportionality large change in the morning and evening peak is a result of the congestion on the highway network during those time periods, meaning the relative attractiveness of bike increases and achieves the mode shift shown on page 67. This results in growth in bike trips beyond the additional demand generated by a larger population.

Walking shows a similar pattern to cycling, but with a more pronounced focus on peak periods of the day.







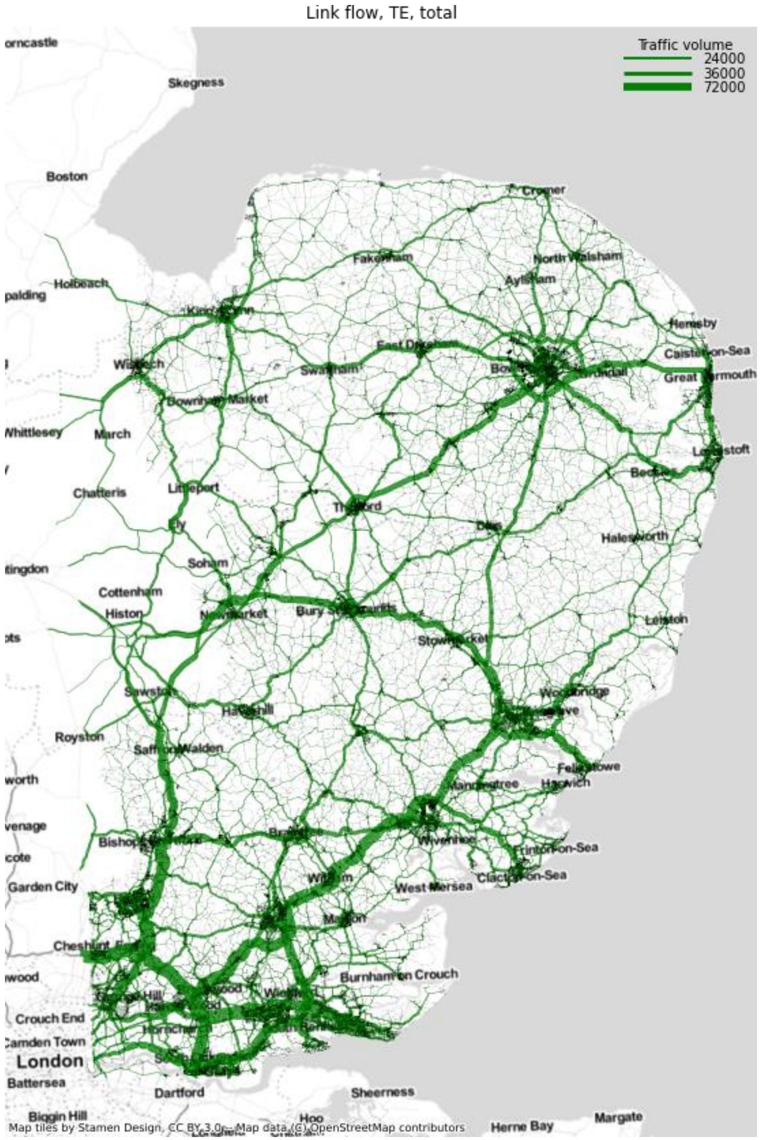
2040 Baseline Network Performance

Daily car flow

The adjacent plot shows daily car flows in the 2040 baseline model. This illustrates the model generates high traffic volumes on the M25 and the rest of the motorway network in the model area, particularly near London, Chelmsford, Ipswich and Norwich. The overall pattern is similar to the 2019 baseline, with increased flows particularly on inter-city connections.

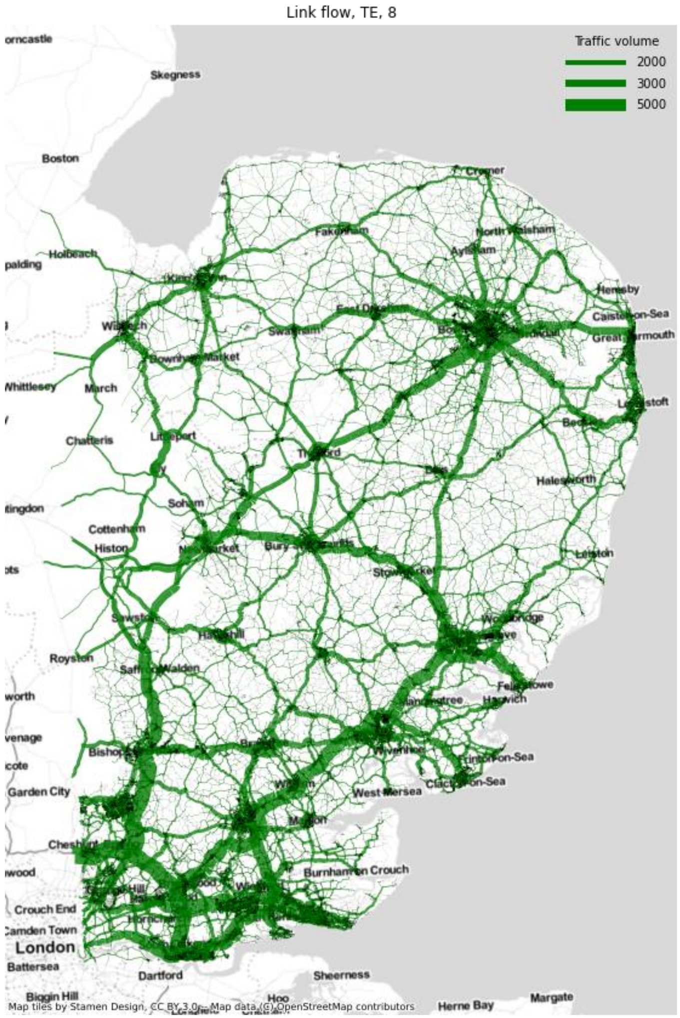
The next page shows equivalent flow plots for the AM peak (8AM-9AM), inter-peak(12PM-1PM) and PM peak (4PM-5PM). The distributions are similar, while overall flows in the PM are highest. The expected reduction in demand during the interpeak is also visible. The Strategic road network (SRN) and Major Road Network (MRN) are clearly visible from the high flow volume links within the model.

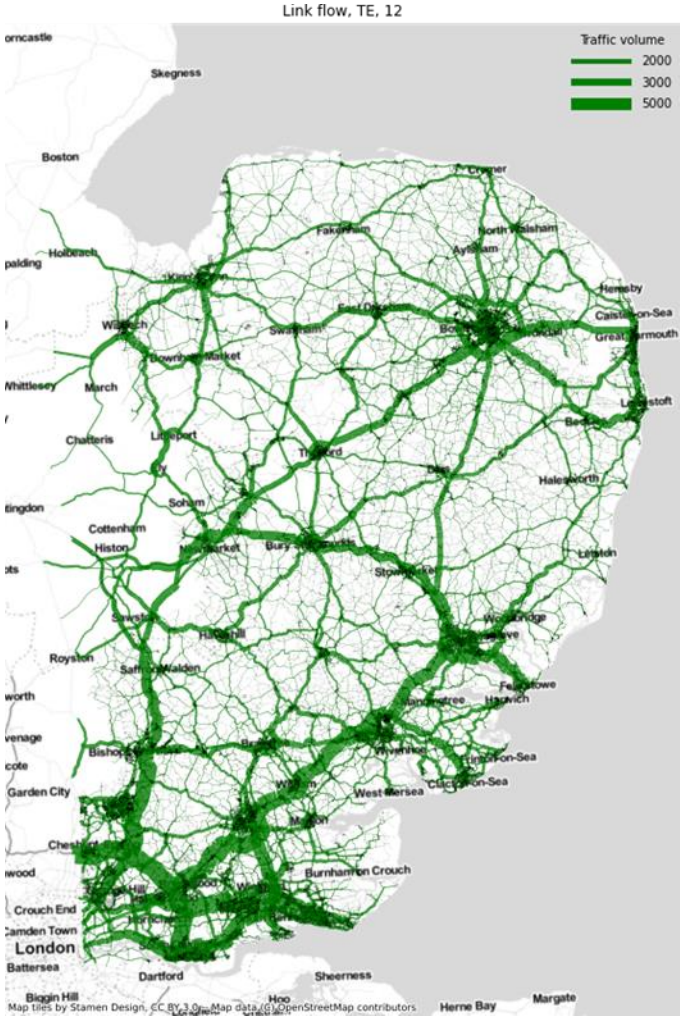
The high-level plots give confidence that vehicles within the 2019 base model at an aggregate level are using key road corridors and the growth to 2040 has not created strange vehicular behaviour at an aggregate level.

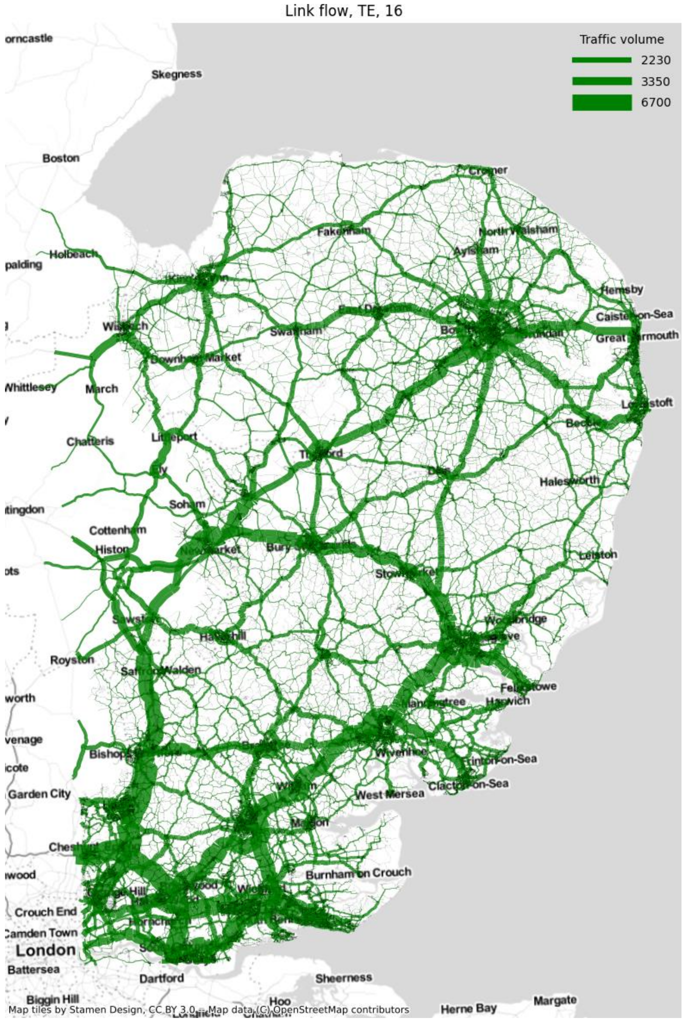


2040 Baseline Network Performance

Peak and interpeak car







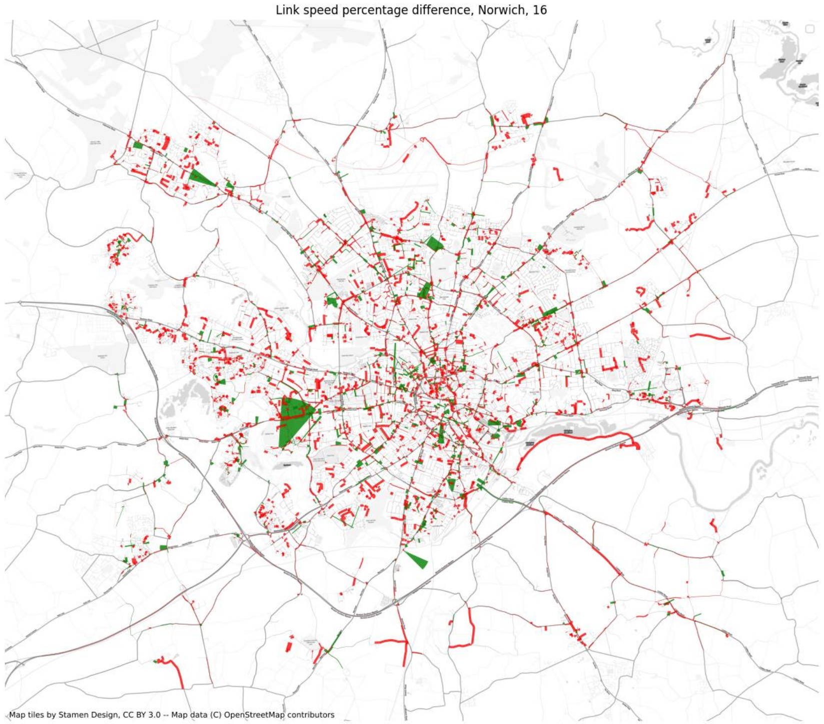
2040 Baseline Network Performance

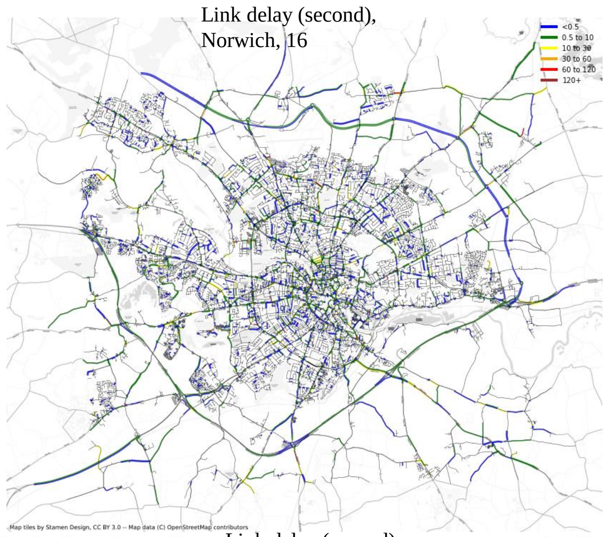
Peak and interpeak speed and delay - 2040 baseline against 2019 baseline

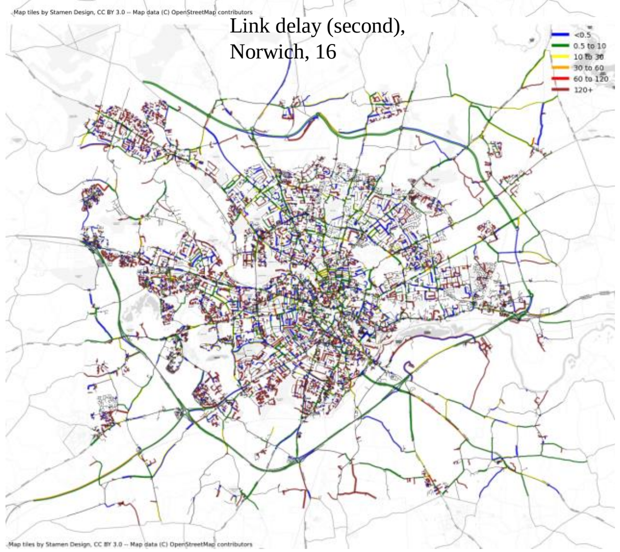
Detailed speed and delay plots have been generated for major towns and cities within the study area and are included within the appendix. The example on this page show the evening peak hour in Norwich.

The link speed plot demonstrates the lower speed across the majority of the network. Much of this change is located on more minor residential streets which may be a result of rat running in the model to avoid congestion.

The link delay plot shows a range of delays across the network, which when compared to 2019 show increase throughout, including strategic links and the local road network.







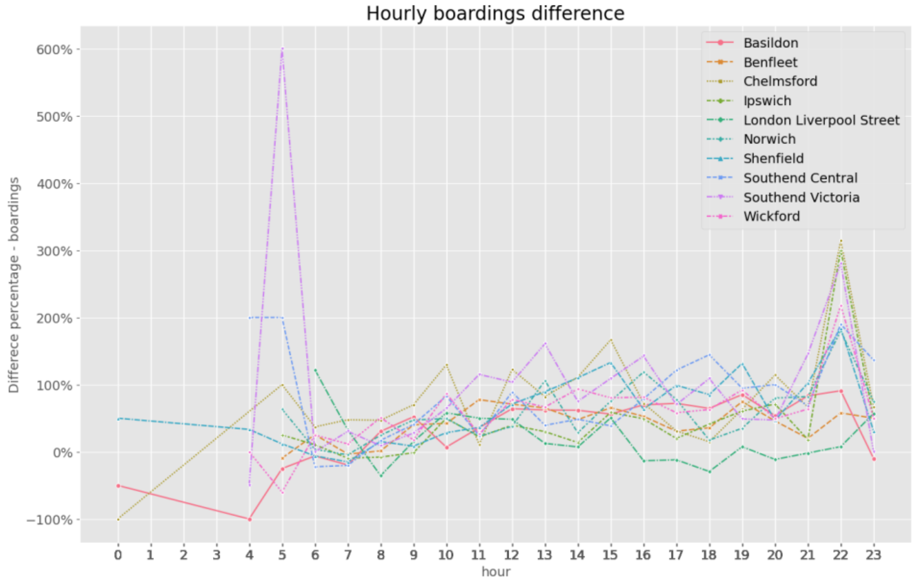
2040 Baseline Network Performance

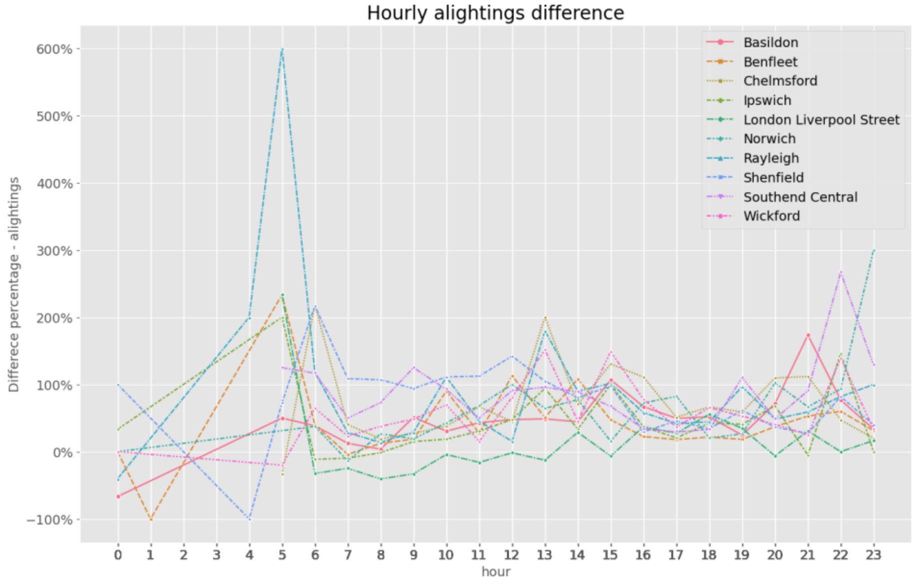
Rail ridership – 2040 baseline minus 2019 baseline

The charts to the right show percentage difference of boarding and alighting counts across the 10 busiest railway stations between 2040 and 2019 baseline.

The increase of ridership is most notably during peak hours, specifically at Southend Victoria and Rayleigh stations in the AM. There is decrease in early morning at some stations, but the absolute number of change is minor.

Part of the increase in rail trips may be the inclusion of the Elizabeth line within the 2040 forecast year networks which increases the attractiveness due to onward connections.





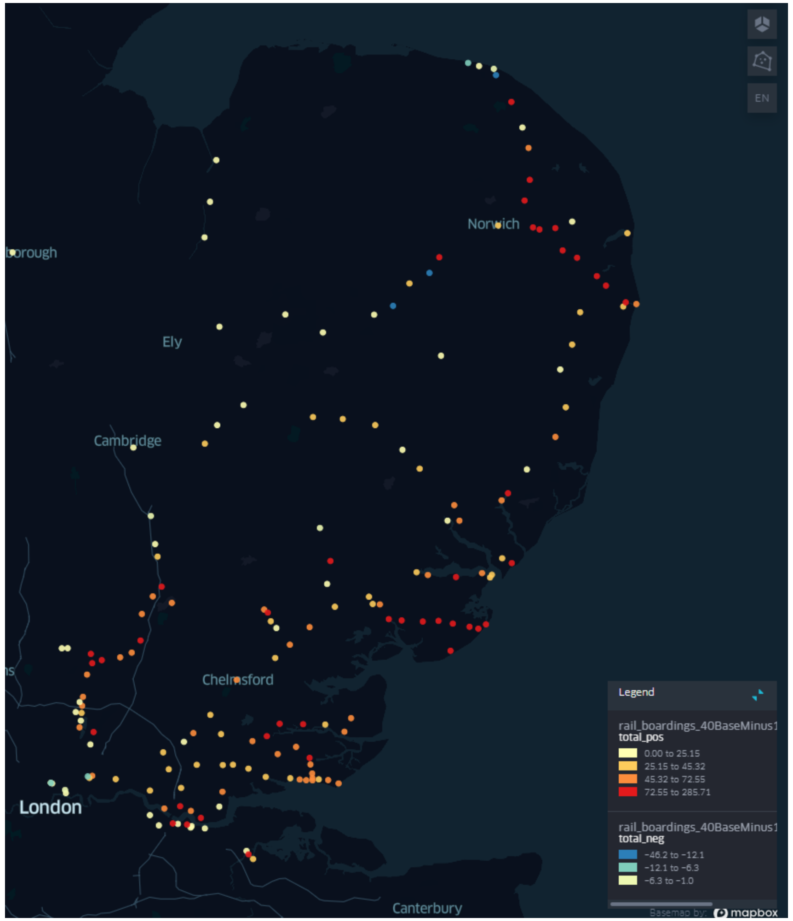
2040 Baseline Network Performance

Rail ridership – 2040 baseline minus 2019 baseline

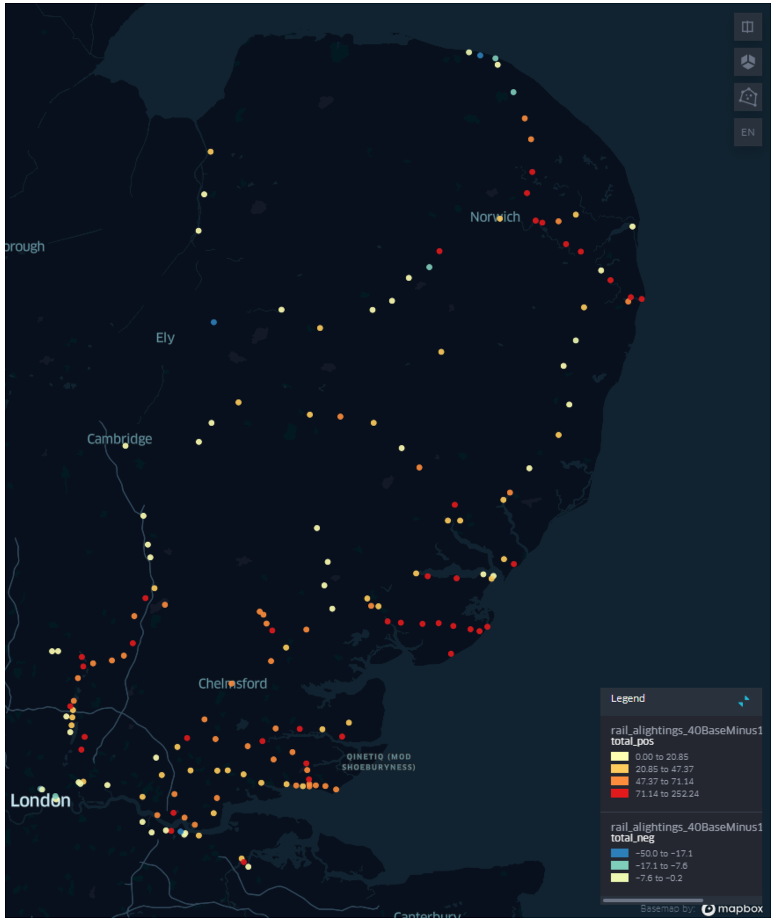
These plots show the Rail ridership change from 2019 to 2040 across the region in baseline scenarios.

The daily boardings and alightings increase in rural areas, particularly in the east coast, and stay stable or even minor decreases in some urban areas. This may be due to a number of rail routes /stations reaching capacity, hence agents choosing to access the network from different locations. Rail station access behaviour is therefore an area that should be considered for further analysis in future work.

Overall, we can see a large increase in the number of rail trips across the study area in 2040.



Rail boarding counts



Rail alightings counts

2040 Baseline Network Performance

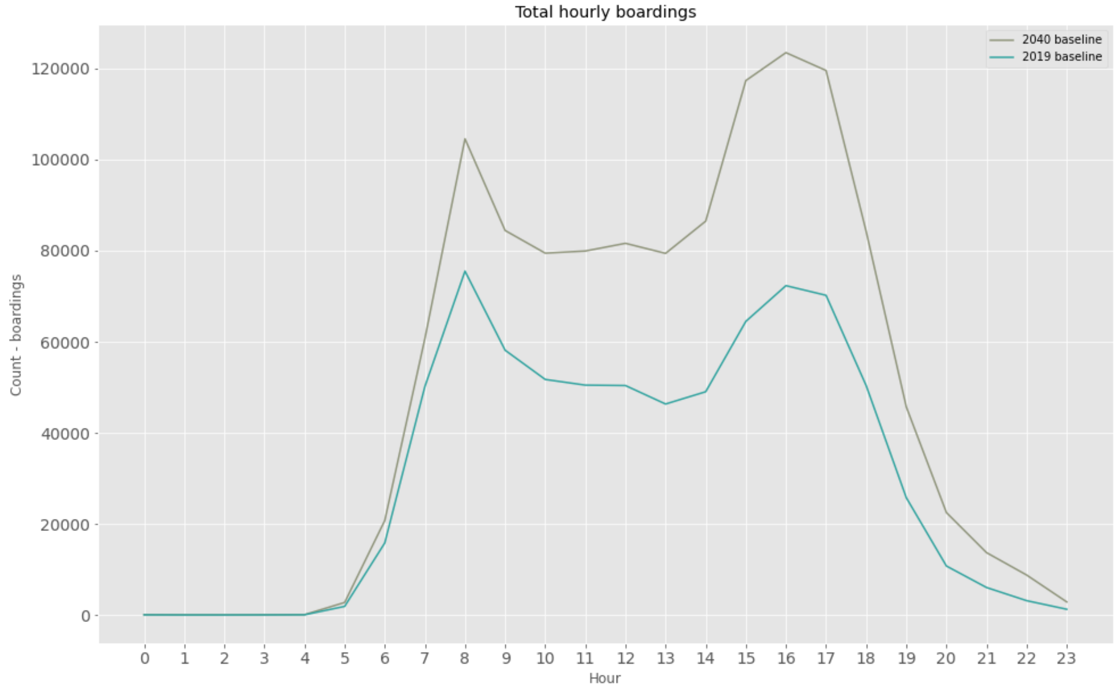
Bus ridership

The figure shows total hourly boardings in the 2019 and 2040 baseline scenarios for the modelled area. The alighting counts are consistent with the boarding counts across the time of the day.

Given the population increase, it is expected to see the increase of total boardings in 2040.

The profile of both scenarios are similar, peaking at 7AM and 4PM. The level of boarding counts stays more stable during inter peak hours in 2040, whereas in 2019 there is a slight drop at 1PM.

The figures on the following page show bus ridership change from 2019 to 2040 baseline scenarios with a focus on Ipswich. Overall, more agents are using bus in the future, particularly along certain routes radiating from city centre. This aligns with the mode shift from car trips to bus trips in the future, which is explained in more detail in the respective section. In some more central locations where there is a reduction in bus use, this may be due to buses being closer to capacity by the time those stops are reached, and agents switching to sustainable travel modes.



2040 Baseline Network Performance

Bus ridership in Ipswich– 2040 baseline minus 2019 baseline

Bus boarding counts

Bus alightings counts

Analysis and insights

- Scenario analysis
- Analysis themes

Scenario analysis

We think about scenario analysis and thematic insights

As we described on page 28, we chose to run the following scenarios as part of this first phase of model development, and have undertaken a range of analysis against a number of themes described on the next page. The insights from these themes are presented across all scenarios, with a summary of the insights from the thematic analysis. Each of these analyses highlights areas for further work. Finally, we then summarise the insights and observations for each of the outputs.

Scenario	Key Question	Changes to Baseline
2040 - Road Pricing Scenarios	What is the impact of increasing per km costs on driving?	Cars, LGVs, and HGVs have their per-km charges increased. This will be across combustion and electric vehicles. Increases; Low: 1.5x, Medium: 2x, High: 3x. These are applied across different vehicle types based on their base 2040 cost per km in the TAG Databook (so EVs remain cheaper to run than combustion cars, but cost more than in the 2040 baseline).
2040 - EV Uptake Scenarios	What is the impact of different levels of EV uptake?	The 2040 Baseline has 33% of private vehicles as Electric Vehicles based on TAG Databook data. We have a scenario at 66% uptake and one at 88% uptake (based on the Vehicle Led Decarbonisation assumptions in the TAG Common Analytics Scenarios). Different EV proportions applied to LGVs, and HGVs assumed to be all combustion (as per TAG data book).
2040 – Active Travel	What would happen if active modes were twice as appealing?	We halved the utility cost of walking and cycling (representing agents having a more positive attitude to these modes). This isn't saying how this could be achieved, but rather considering the impacts from this improvement.
2040 - Combined Scenario	If we combine scenarios, how close do we get to net zero?	This final scenario combines the highest level of road pricing used above, with the highest level of EV uptake, and the active travel utility boost.

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Analysis themes

We think about scenario analysis and thematic insights

Short trips

Short trips are inherently more able to be walked or cycled, and we can look at how mode choice for these trips changes across the scenarios.

Mode shift

Agents change the modes of transport they use to maximise their outcomes. Looking at how these mode choices shift between different modes is a way to understand the detail of what changes in a scenario.

Carbon

Our key analysis from this phase of development has been to look at how each of our scenarios contributes to the decarbonisation of the transport network and how different interventions interact.

Equity

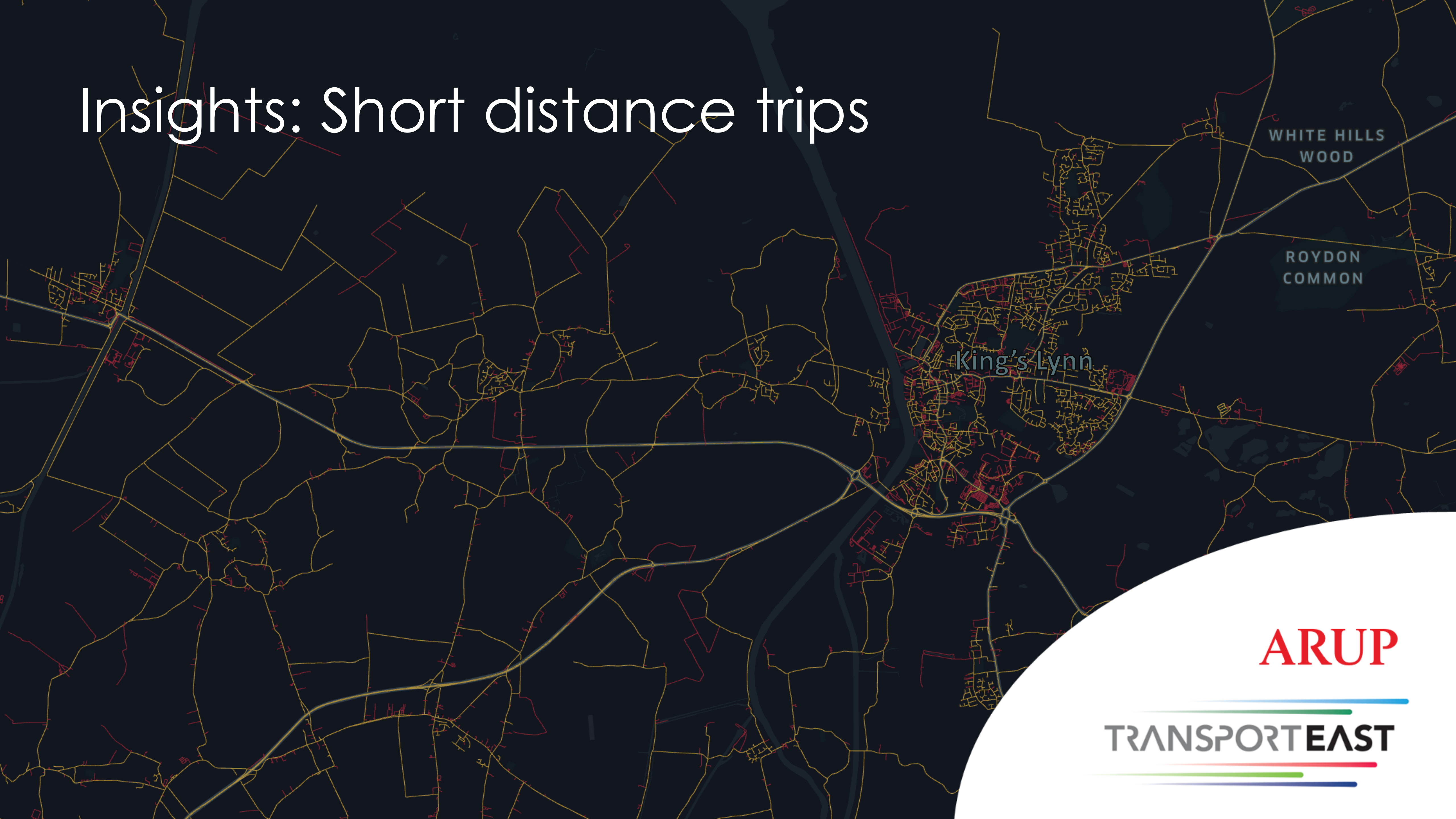
Agent level detail means we can look at who is impacted and how different groups of people are differently impacted by different interventions.

Agent utility

Agents measure their day by looking at utility, gained from completing activities, and lost from spending time and money travelling. Looking at the scores agents experience in their selected and unselected plans gives us insight into their experience.

A note on analysis and insights: The quantity of information generated from the model is huge, and many of these analyses could be extended and deepened in response to specific questions. We have tried to strike a balance between breadth and depth to showcase the potential for this modelling approach.

Insights: Short distance trips



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Insights: Short distance trips

Short trips mode share

Short distance trips within the Transport East region are important given the desire to increase active travel and reduce car journeys. Short trips are key targets for modal shift to active modes (walking and cycling). For this assessment we consider two different trip distance bands:

0 - 2km: high potential walking, shorter distance bike

2km - 5km: high potential cycling, longer distance walking

The 2019 baseline model results are provided in the table. For trips under 2km, 60% of trips already travel by sustainable modes, highlighting the convenience of walking and cycling at this distance. For the 2-5km band, over 77% of trips are undertaken by car. This highlights a substantial number of short trips that could be targets for modal shift to sustainable modes.

Mode	Mode Share of 0-2km trips 2019 Baseline	Mode Share of 2-5km trips 2019 Baseline
Walk	55.9%	12.5%
Bike	3.6%	4.1%
Bus	3.3%	5.7%
Rail	0.0%	0.2%
Car	37.2%	77.5%

It is also positive to see that rail doesn't account for any trips under 2km, and a very small proportion of trips between 2-5km. Bus captures a higher mode share, which is consistent with what would be expected.

The model currently may have some under-representation of short trips due to their under-reporting in the National Travel Survey dataset, which is an area for future focus in model development. However, we expect the behavioural responses seen in this section will be consistent with future development.

Given the baseline performance of short distance trips and the Transport East scenarios developed for this study, we have kept this analysis at a regional level. A more detailed analysis of these behaviours, segmented spatially, by agent attributes, activity types, and time of day could provide greater insight as part of a more detailed study area scope. This could be aligned to specific policy or infrastructure interventions and include greater verification of baseline performance.

Insights: Short distance trips

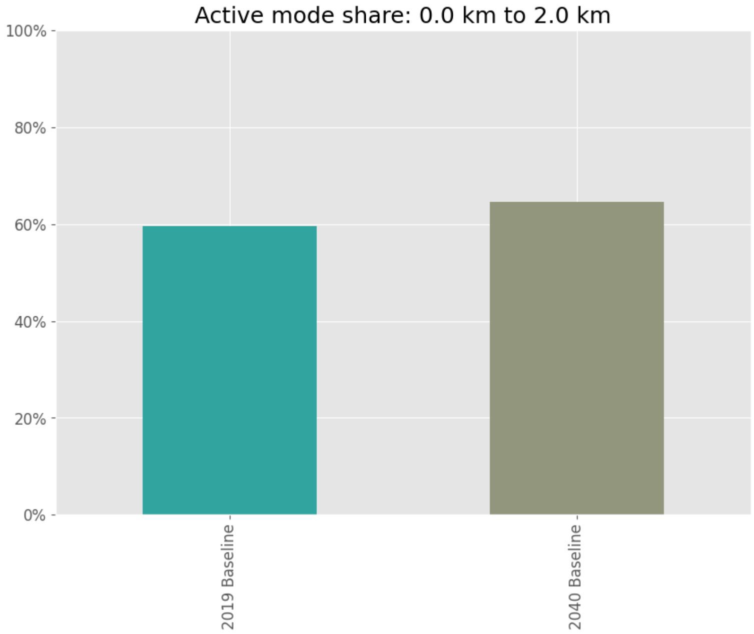
2019 Baseline vs. 2040

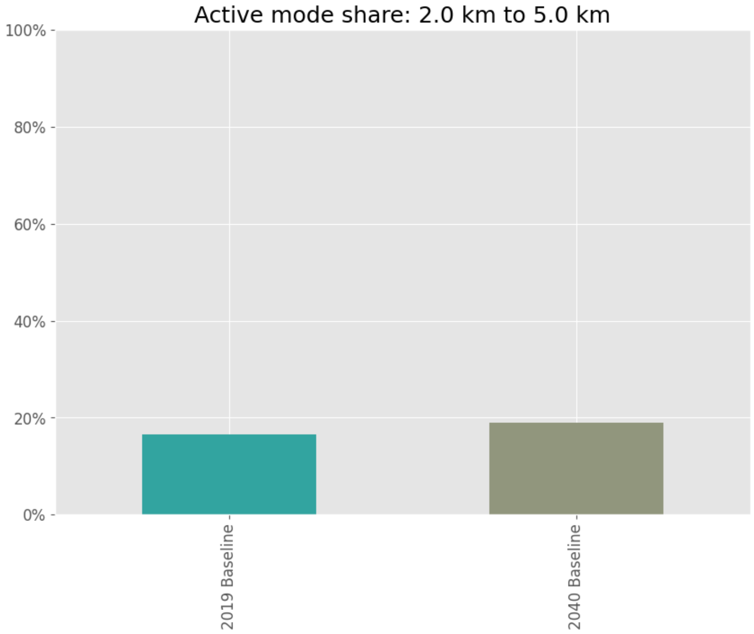
When considering changes to short distance trips between the 2019 and 2040 baselines, the simulation shows we have an increase in the active mode share over time.

The greatest increase is in the under 2km category from 59.6% to 64.6%, this represents an 8% increase from the baseline. In the 2-5km category, the increase in mode share is only 2.5%, but this is a 15% increase from the 2019 baseline give the low start point.

This is consistent with general observations about the 2040 baseline earlier in the report, demonstrating an overall increase in trips due to population growth that is greater than the additional road capacity. This means that congestion, and hence journey times, are higher in 2040.

Because walking and cycling are not impacted by congestion in the model, they provide an attractive alternative for agents with their use is increasing over time.

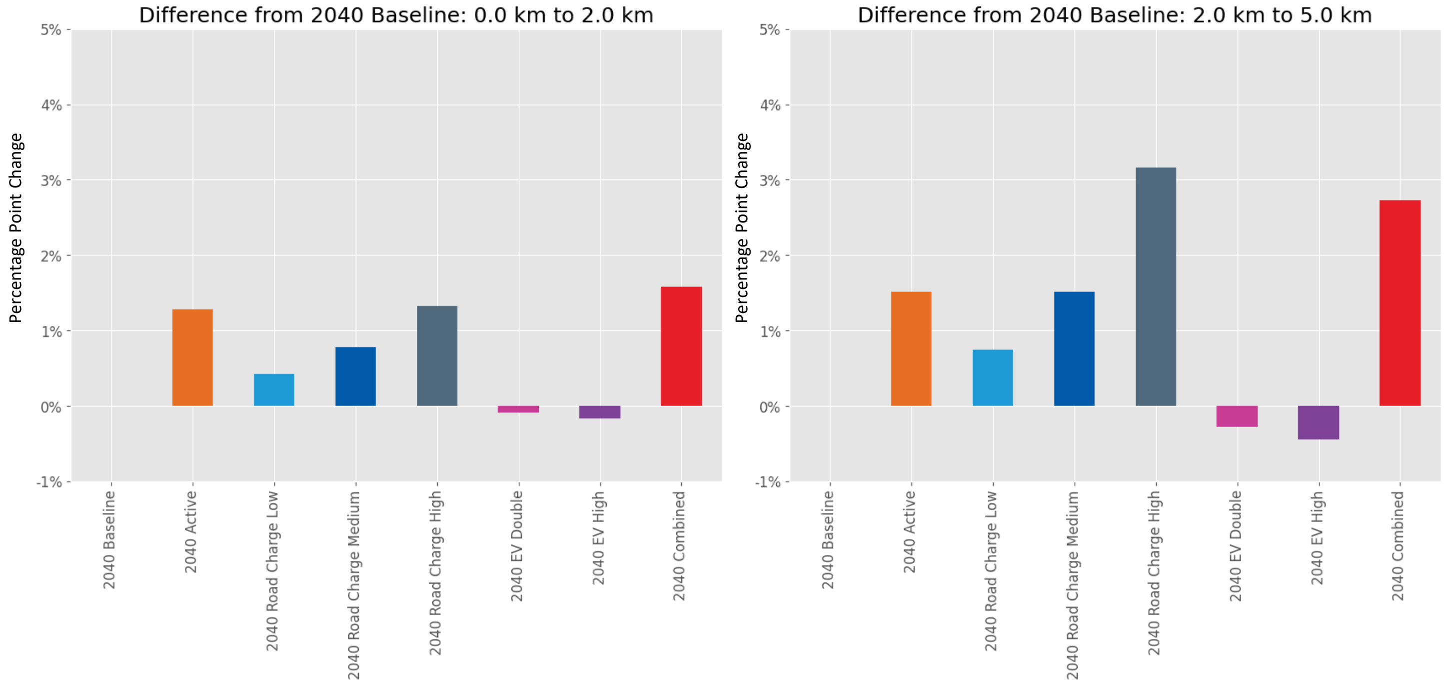




Insights: Short distance trips

Scenario variations: Potential active trips

The figures on this page illustrate the change in active travel mode share for each of the 2040 simulation scenarios.



Unsurprisingly, increasing the attractiveness of active modes creates an increase in the active mode scenario of 1.3% for 0-2km trips, and 1.5% for 2-5km trips. This is a trivial result; however, we see more interesting outcomes in the other scenarios.

The road pricing scenarios improve mode share proportional to the additional costs placed on car users, and impact the 2-5km trips is the most significant shift at 3.2%pt. This is because a larger proportion of trips within that group were taken by car in the baseline, and therefore affected by road user charging. The EV scenarios are the most interesting, reducing active mode share by 0.2%pt for 0-2km trips and 0.3%pt for 2-5km trips. This is because EVs make driving relatively cheaper, and hence more appealing to use for shorter trips for agents who own one. The combined scenario shows this same behaviour, improving mode shares in the 2-5km trip band by less than the highest road pricing scenario. Here the impact of 88% EV uptake reduces the benefits gained from the additional road charging. A full data table is presented on the next page.

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Insights: Short distance trips

Data table

Scenario	Active Mode Share (% of trips)		Shift (%age pt) from 2040 Baseline		Change (%) from 2040 Baseline	
Distance Band ->	0-2km	2-5km	0-2km	2-5km	0-2km	2-5km
2019 Baseline	59.6	16.6				
2040 Baseline	64.6	19.0				
2040 Active	65.9	20.6	+1.3	+1.5	+2.0	+7.9
2040 Road Charging Low	65.0	19.8	+0.4	+0.7	+0.6	+3.9
2040 Road Charging Medium	65.4	20.6	+0.8	+1.5	+1.2	+8.0
2040 Road Charging High	65.9	22.2	+1.3	+3.2	+2.1	+16.6
2040 EV Double	64.5	18.8	-0.1	-0.3	-0.1	-1.4
2040 EV High	64.4	18.6	-0.2	-0.4	-0.3	-2.4
2040 Combined	66.2	21.8	+1.6	+2.7	+2.4	+14.3

Short distance trips: Insights summary

We must be wary of undesirable outcomes from large policy shifts

What is the analysis: We are able to look at different types of trips, in this case filtered by trip length. We looked at trips between 0-2km and 2-5km and their mode.

Key takeaways:

- Short trips in the model align with current understanding of active and other modes, with walking being the dominant mode under 2km (56%), and car being dominant in the 2-5km bracket (78%).
- There are significant numbers of trips under 5km in the simulation that could be active, but are instead driven. There is huge potential to shift 2km to 5km trips away from car.
- Road pricing increases the number of people using active modes, proportional to the size of the charge, this is more significant at the 2-5km trip band with a 15% increase in sustainable in trips (high road charging).
- EV Uptake, without associated price interventions, is likely to decrease active modes for trips under 5km.

Further work:

- Focused study on active modes for these distances. This will be especially interesting aligned to a specific town or area.
- Recommend addressing some of the short trip distributions in the base model as part of this work.

Insights: Mode shift

Insights: Mode shift

How do agents change their mode choice?

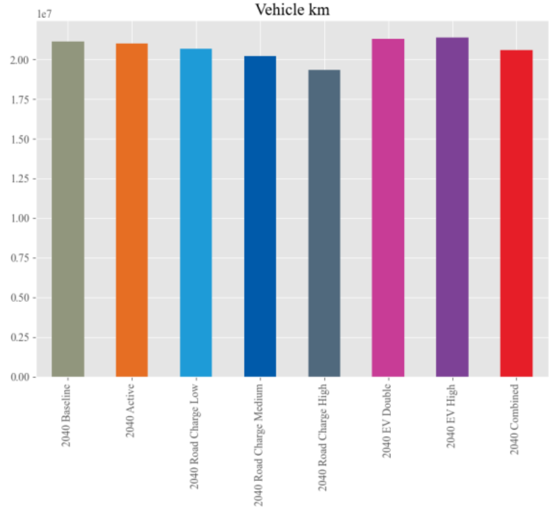
Decarbonisation through the removal of emissions from the network is unlikely to be significant enough to fully decarbonise the transport network. Additionally, if we are to address issues of network capacity and performance, transport demand needs to be managed.

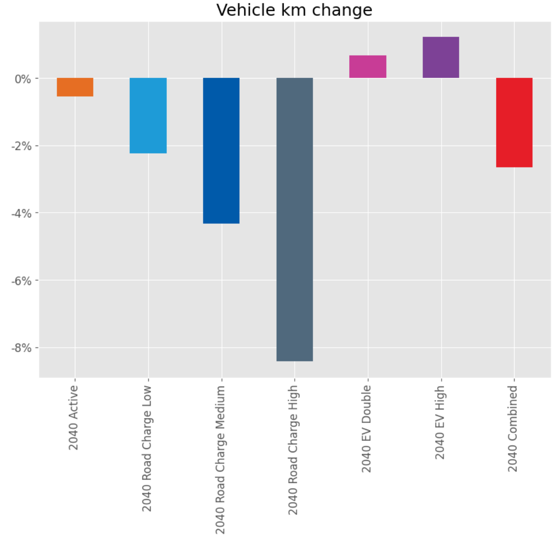
As shown in the 2040 Baseline and equity insight sections, the network within the region is very car dependent, and if population growth forecasts are accurate, the overall performance of the network will degrade. This will make agents consider switching to public transport, however, lots don't have viable public transport options.

Modal shift is critical, we need to find ways to incentivise people moving from cars to non-car modes. In the future, this will require a range of interventions, from demand management, behavioural change, pricing interventions, and changes to the network. Some of these changes could involve new public transport services, demand responsive services, or infrastructure like Park and Ride.

The charts below show the challenge the Transport East region faces. While the scenarios show a reduction in vehicle km, they are a very small adjustment to overall distance travelled.

The only scenarios that show an increase in vehicle km are the EV scenarios. Electric vehicles, with their lower cost per km, encourage people to drive for more journeys, and shorter journeys (as seen in the short trips insights).





Insights: Mode shift

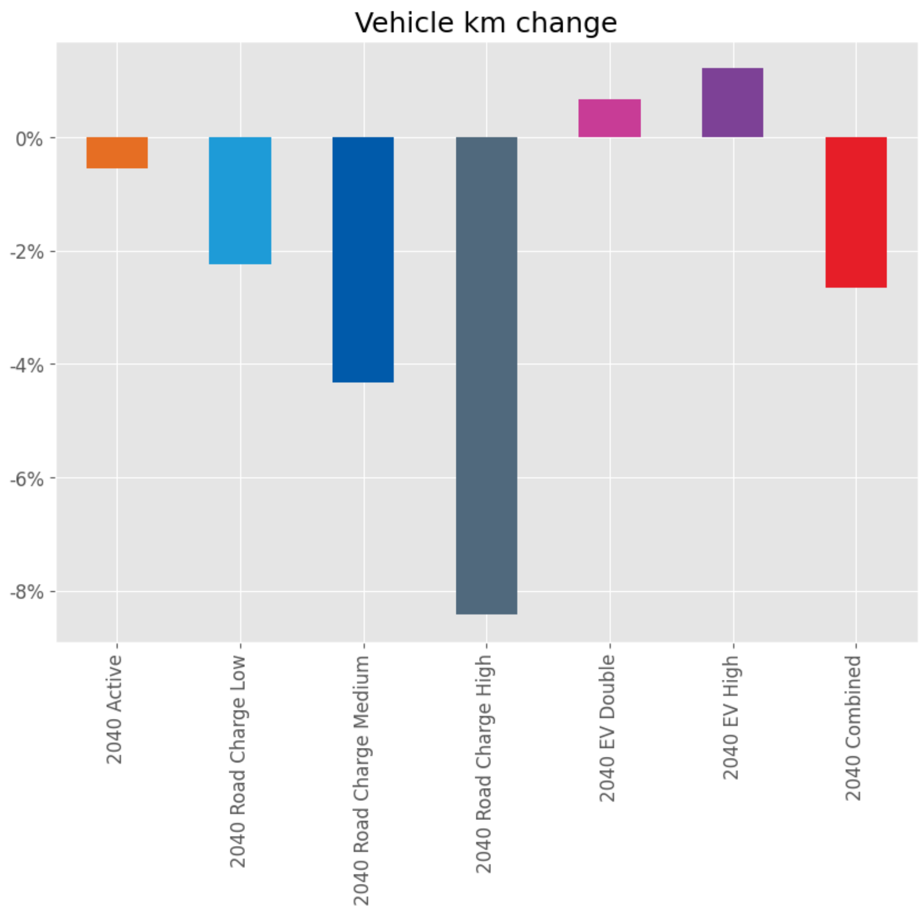
The simplest metric for us to look at is vehicle km

The road pricing scenarios present the highest reduction of vehicle km across all of our 2040 simulations. The reduction of vehicle km increases as pricing is imposed. We examine some of the impacts the scenarios have on different agent groups in the equity insights section. It appears as if this effect increases exponentially, with the same price increases having increasing efficacy in changing behaviour.

These charging scenarios were very much a ‘push’ strategy to change behaviour, penalising those who are using cars. The ‘pull’ strategy of making active modes more appealing resulted in a much smaller shift. However this is to be expected given the dominance of car in the model and the distances agents travel in the model.

The EV uptake scenarios result in higher total distance travelled, because EVs cost per km is roughly 25% of the cost of combustion vehicles. This is in line with the TAG databook but may be unrealistic by 2040.

Finally, the combined scenario shows an interesting effect, overall vehicle km change is significantly less than the high road pricing scenario. The base cost of each km in an EV devalues the impact of road charging based on the factors used in our scenarios.



Insights: Mode shift

What happens to non-vehicle modes?

Looking at vehicle km shows one side of the modal shift picture. If we want to understand the motivators for agents to change away from vehicles, we need to look more at the balance of the other modes available to agents.

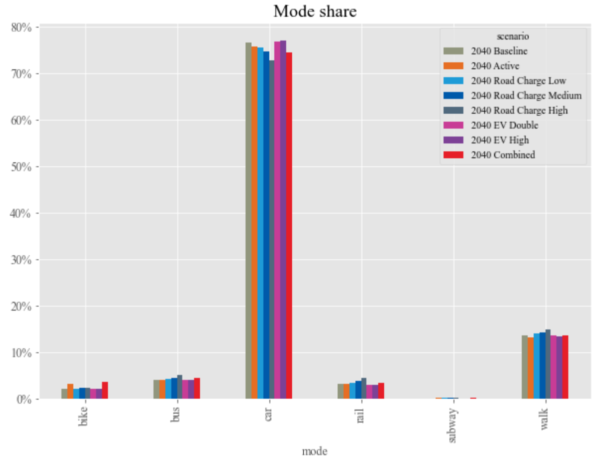
Mode share for the other modes presents a consistent picture with a lot of the other analysis we have done with this first cut of the model.

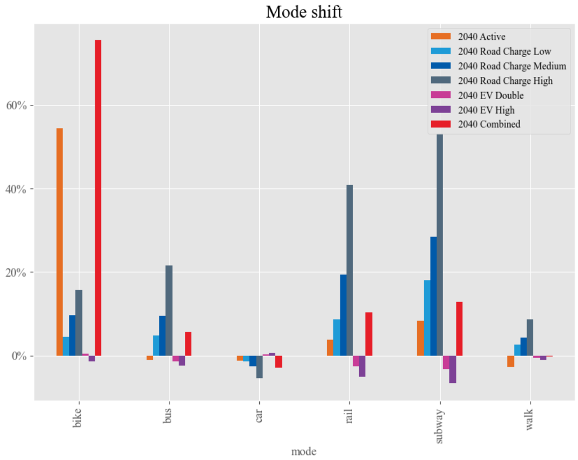
The active scenario shows a huge shift to bike modes, but not walking, due to cannibalisation of walking trips by bike (see page 93). This is even more pronounced in the combined scenario, with road charging increasing the relative utility of cycling even more. This combined effect is interesting to observe. Note that this large shift is due to a very low base for cycling.

It is worth noting that the active scenario also impacts on public transport. Bus, expected to be shorter distance trips, loses mode share to cycling. However, rail and subway increase mode share under the active scenario, reflecting the benefit that agents get from access and egress to stations using active modes.

As seen with the vehicle km analysis, shift away from car and to public transport in the road pricing scenarios increases as the level of the charging does.

All modes except for car show a reduction in usage in the EV scenario, especially the public transport modes. This is due to the increased convenience and relative reduction in price of driving in these scenarios.





Insights: Mode shift

How to read these charts

Understanding overall mode shift at an aggregate level is interesting, but it is also valuable to see the flow of users between modes. These charts provide one way of doing that, showing **net mode shift**. The first thing to note is that these charts are symmetrical along the diagonal, and can be read in a couple of ways.

Most intuitively, we read across a row to look at where agents from that mode have gone in the scenario. In the example to the right, we can look at the 'car' row and see that 39,770 trips have moved from car to bike, and 190,220 have moved to rail. These are complemented by negative versions of these numbers in the mirrored along the diagonal.

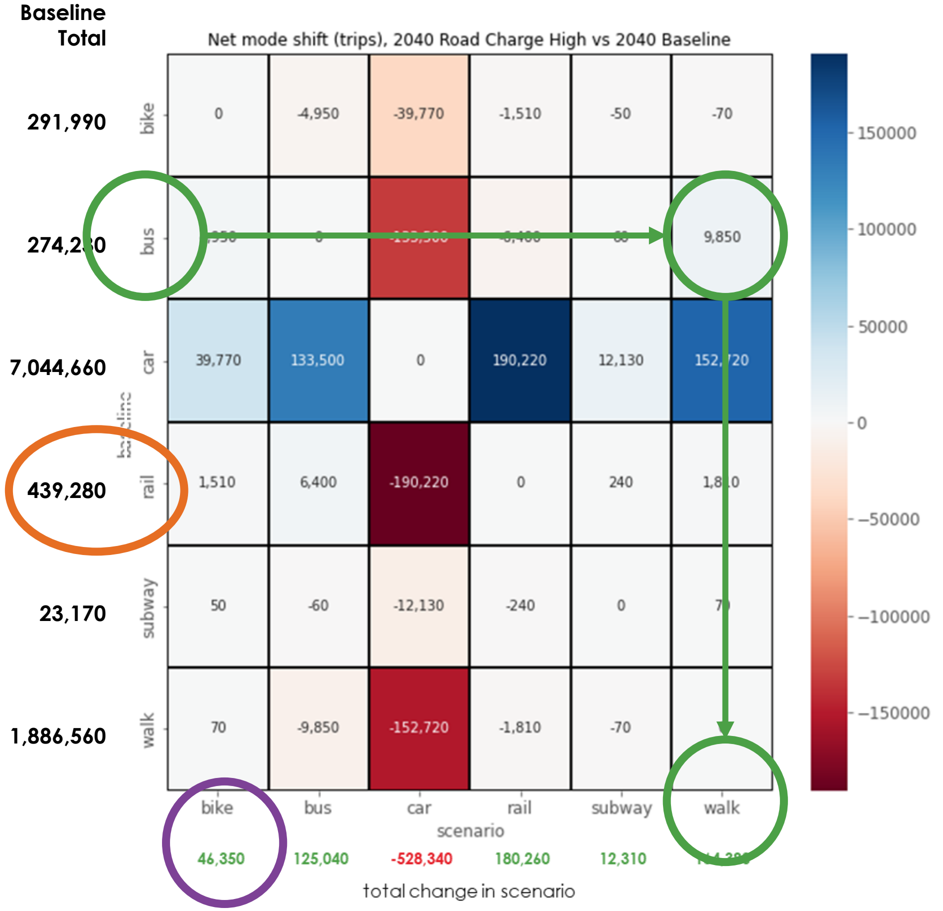
In reading these charts, **we recommend reading across the row looking for positive numbers**, as these are more intuitive; 39,770 agents moving from car to bike is easier to understand then -39,770 agents moving from bike to car.

Finally, these figures are net change. If, in a single scenario, 100 agents move from rail to bike, and 100 agents move from bike to rail, the overall net change will be 0.

"9,850 agents (net change) from the baseline switched from bus to walking in the scenario"

"Bike gained 46,350 trips in the scenario"

"Rail has 439,280 trips in the 2040 Baseline"



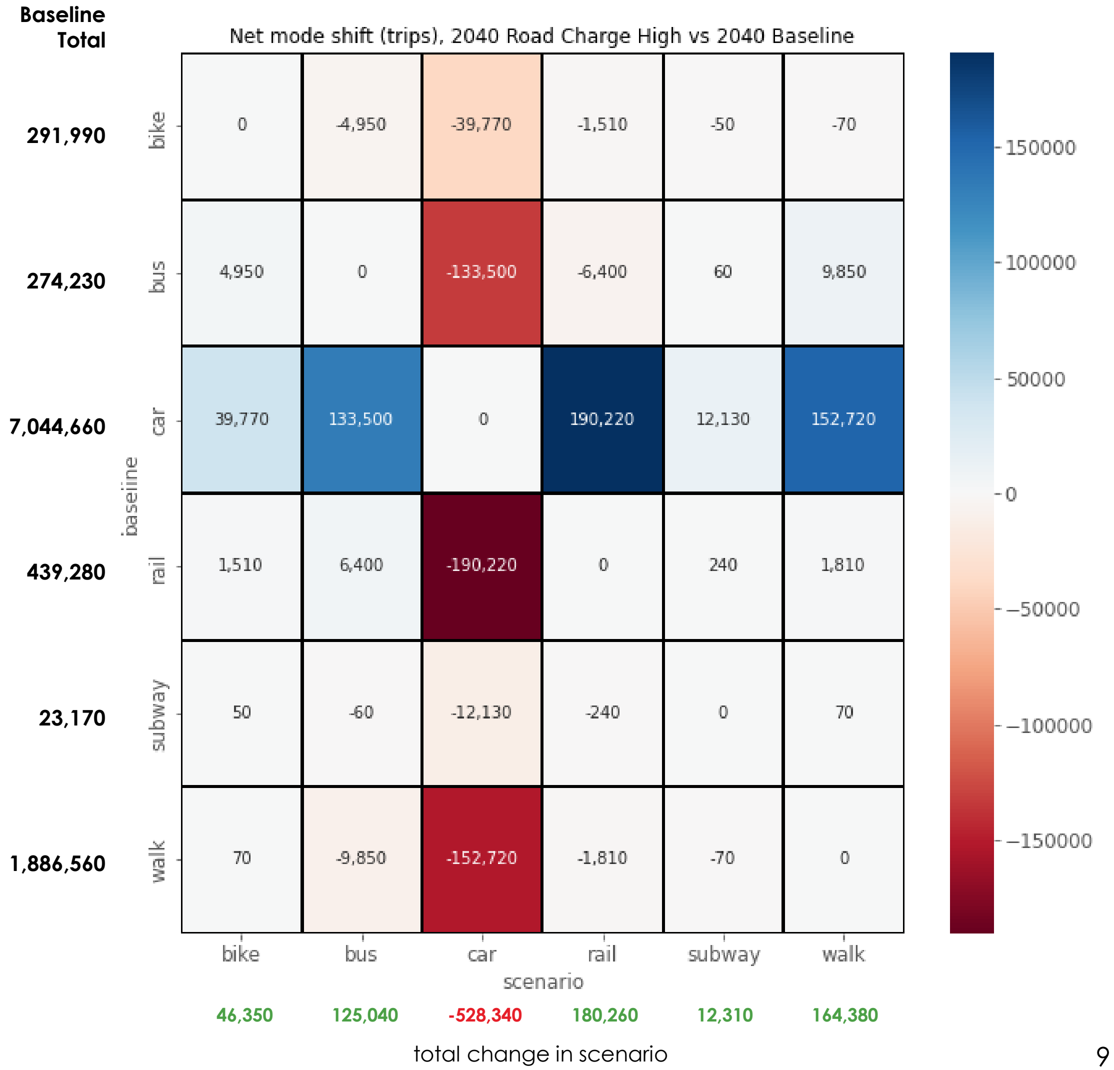
Insights: Mode shift

Road charging mode shift

The figure presents the highest of the road charging scenarios, as the low and medium charge variants show similar patterns, just at a lower level. The full set of these transition plots can be seen in the appendix.

As would be expected, the figure shows a shift to all other modes from car, with rail, then walking, and finally bus benefitting the most. This implies that all trip distances are impacted, and the change in walking trips almost certainly represents the shift in short trips that we see in the short trip insights.

We see that both bus and rail have significant increase in trips in this scenario (41% more for rail, 46% more for bus). Interestingly, we also see a shift away from bus to walking and cycling. This is due to a lack of capacity on bus services, resulting in agents moving away from bus. We look at this in more detail on the next page.



Insights: Mode shift

Road charging mode shift

The number of trips where an agent is unable to board the first bus arriving to their stop due to insufficient capacity increases by 63% in the "high charge" scenario. Having to wait for the next bus with available space increases overall journey times, and encourages some users to shift to alternative modes, such as walk or cycle.

As expected, those events happen more often in urban areas, or areas with higher rail use. The latter may be related to multi-modal trips: the increase in patronage of some rail services is likely putting pressure to bus lines feeding them.

Overall, and unsurprisingly, making driving more expensive moves people away from cars and onto other modes, but there isn't necessarily sufficient capacity on public transport modes to accommodate them.

In reality, this effect would likely be more pronounced as bus capacity is greater in the simulation (we run a 10% simulation and a 20% bus capacity, this avoids issues at smaller sample sizes where buses could be smaller than a singe agent). Crowding is usually not an issue outside of major cities, however with the modal shift we see in this scenario, it is a limiting factor.

Subsequent work would be required to further model and understand this important issue.

Number of legs not able to board on the first suitable bus due to insufficient bus capacity

Insights: Mode shift

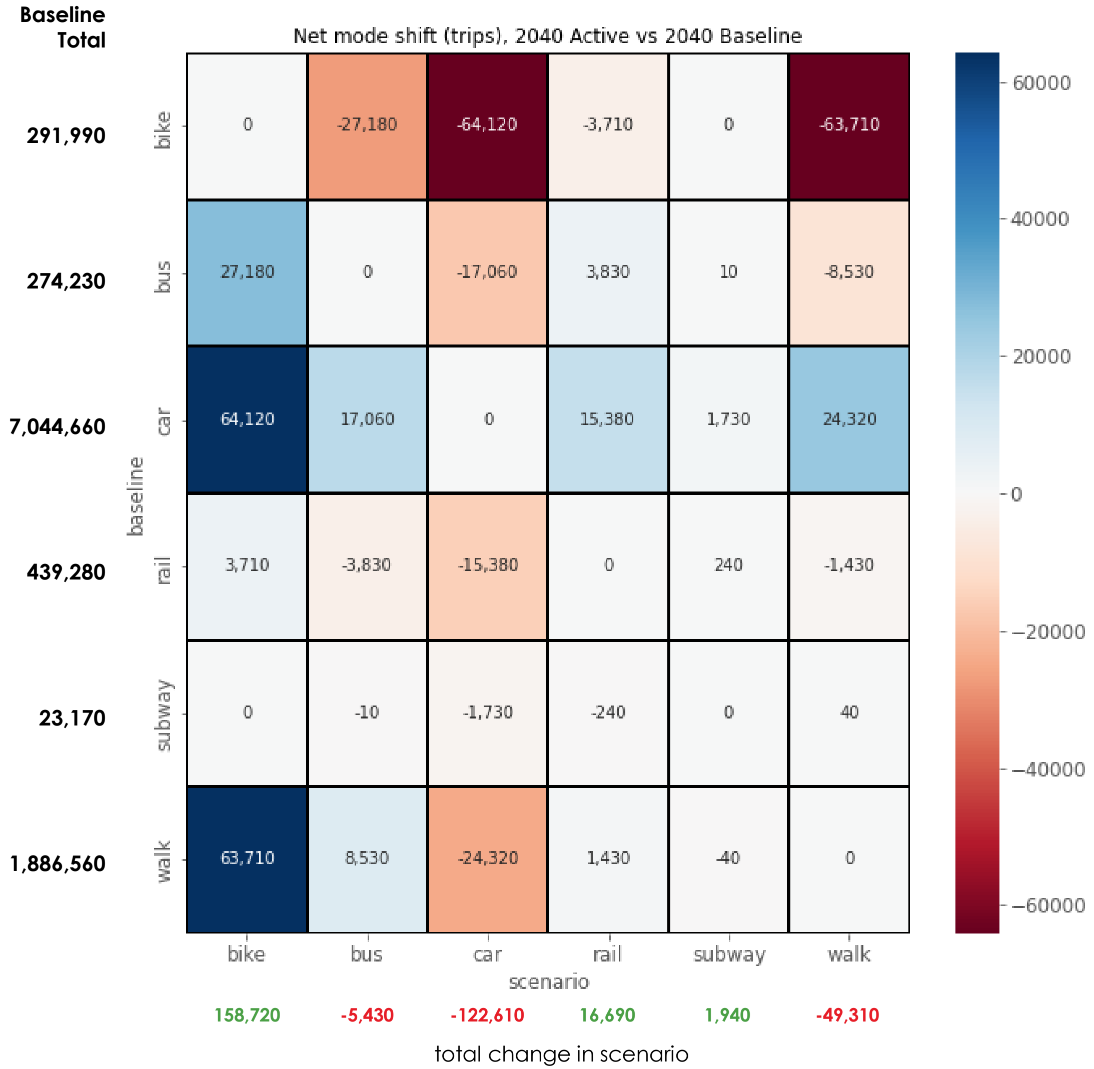
Active mode improvement

The active scenario, as expected, sees a strong move to bike, with net 158,720 additional trips being undertaken by bike.

Car is a consistent loser in this scenario, not gaining on any other mode and losing mode to both walking and cycling. It is also worth noting that the public transport modes also benefit in this scenario, with a 17,060 net trip shift from car to bus, 15,380 from car to rail, and 1,730 from car to subway. These will all be multimodal trip chains where agents are now choosing to walk or cycle to or from a station and catch public transport rather than driving.

As previously noted, we don’t see an increase in walking, despite an equal improvement in utility as biking. This can be seen in the lower left of the transition diagram, with 63,710 walking trips shifting to bike. We also see 8,530 walking trips being converted to bus trips in the scenario.

This shows that improving the appeal of walking and cycling has knock on effects to longer, multimodal trips. This highlights station access and egress as an important focus for future demand management and behaviour change.



Insights: Mode shift

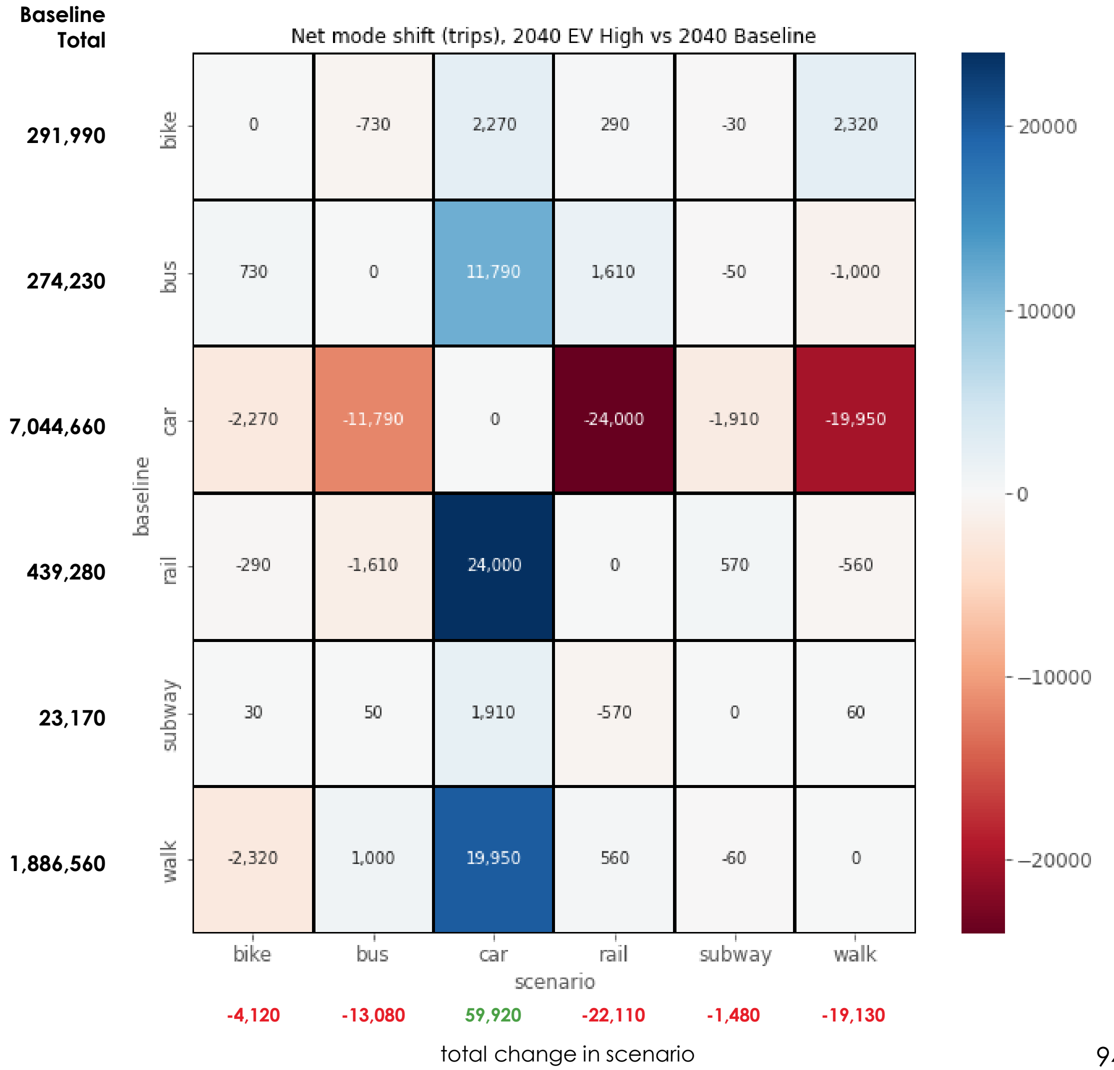
Electric vehicle scenarios

Electric vehicles are very beneficial from a carbon emissions perspective, however, we see here that they introduce a range of negative behaviours in the simulation. Again, we look at the highest EV uptake scenario as the patterns are the same with the low scenario.

Car is the major beneficiary in this scenario, with a net growth in trip share from all other modes. This implies that cars are now even more attractive for all trip purposes, distances, and durations.

The two largest losers in this situation are rail (net 24,000 trips lost to car) and walking (net 19,950 trips lost to car), showing that the reduced cost of operating an EV is impacting the longest and shortest trips agents are undertaking. This is consistent with what we see in the short trips insight.

While this represents a negative overall picture of the impact of EVs on mode share, the absolute values are much smaller than we see for the road pricing scenarios.



Insights: Mode shift

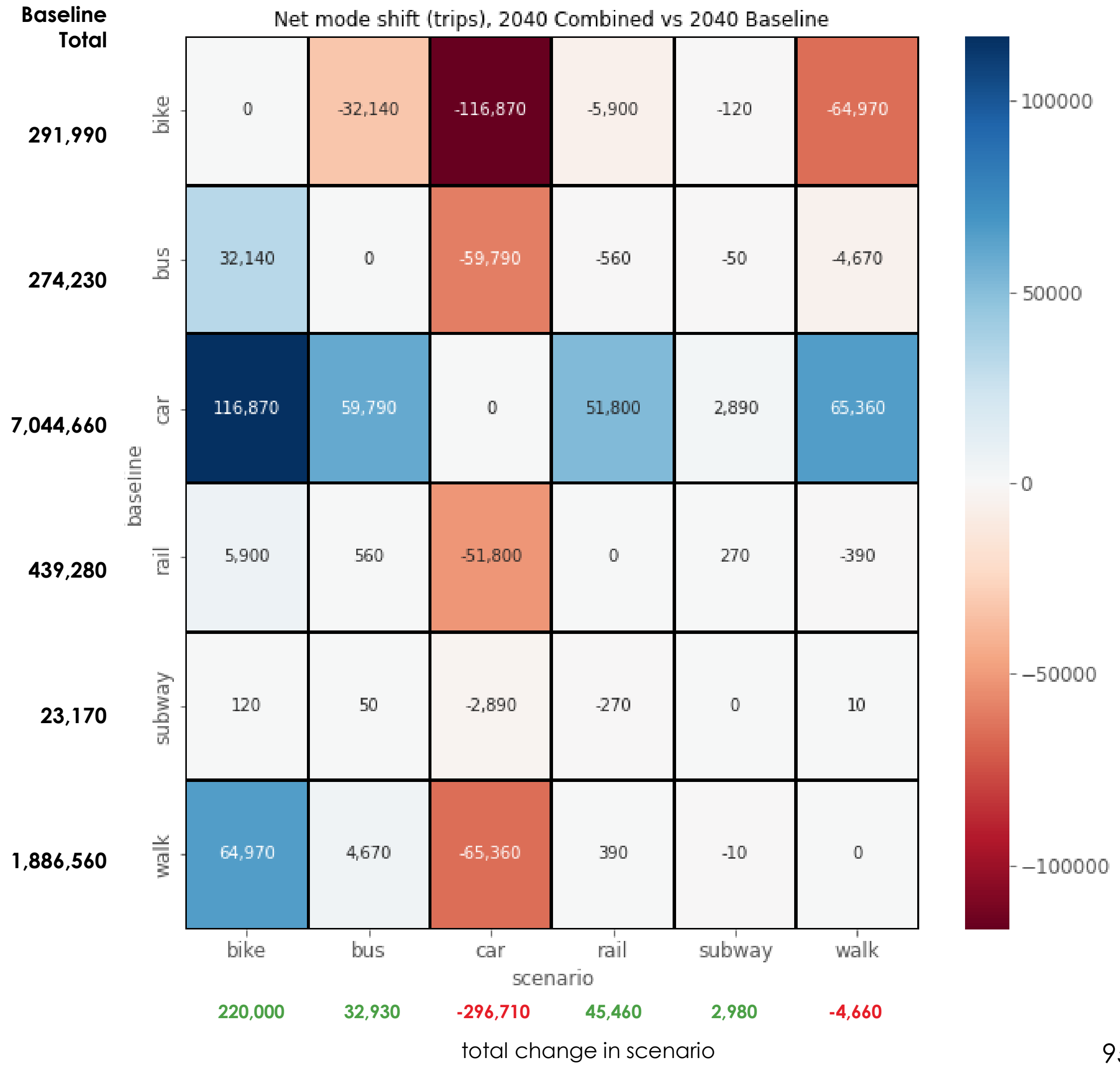
Combined scenario

Given what's been shown in the road pricing and EV scenarios, the combined scenarios shifts are more moderate than expected, coming in at a total of 296,710 net trips shifted away from car, compared to 528,340 for the road pricing scenario.

This highlights one of the core messages that is coming from this analysis, that road pricing is very effective at driving people away from using their cars, but that change is significantly diluted by higher and higher shifts towards electric vehicles (assuming that the assumptions on vehicle pricing for 2040 hold true).

In this combined scenario, we see the influence of the active travel boost in the growth of biking trips, and see the same pattern as in the active travel scenario, with 64,970 net trips shifted from walking to cycling.

There are opportunities to benefit from deploying different interventions in combination, but net effects may not be as great as a single intervention in isolation. Testing these kinds of combination scenarios was highlighted by stakeholders as very desirable, and this is borne out in the analysis.



Mode shift: Insights summary

We must be wary of undesirable outcomes from large policy shifts

What is the analysis: We look at agents' choice of different modes in different scenarios, and how the transition of agents between modes can give us insights into decisions.

Key takeaways:

- The active scenario results in more cycling, as well as public transport use through improved access and egress. This should be a focus for future demand management.
- The Road Charge scenarios result in the highest shift away from car (~20% reduction in the "high" scenario). These may impact different agent groups differently (see equity and agent utility insights).
- The EV scenarios make car slightly more attractive, due to the lower operating cost of EVs.
- Higher levels of EV uptake counteract the impact of future road pricing under current assumptions. Finding ways to make cars (including EVs) less appealing for shorter journeys is needed in order to protect bus and active travel mode shares.

Further work:

- It is possible to dive deeper into these different analyses, and combine with some of the other insights in this study.
- The active travel improvement here was a change to the appeal of walking and cycling, investigating how this could be realised is something that would be done outside the model, but could be implemented in future agent behaviours.

Insights: Carbon

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Insights: Carbon

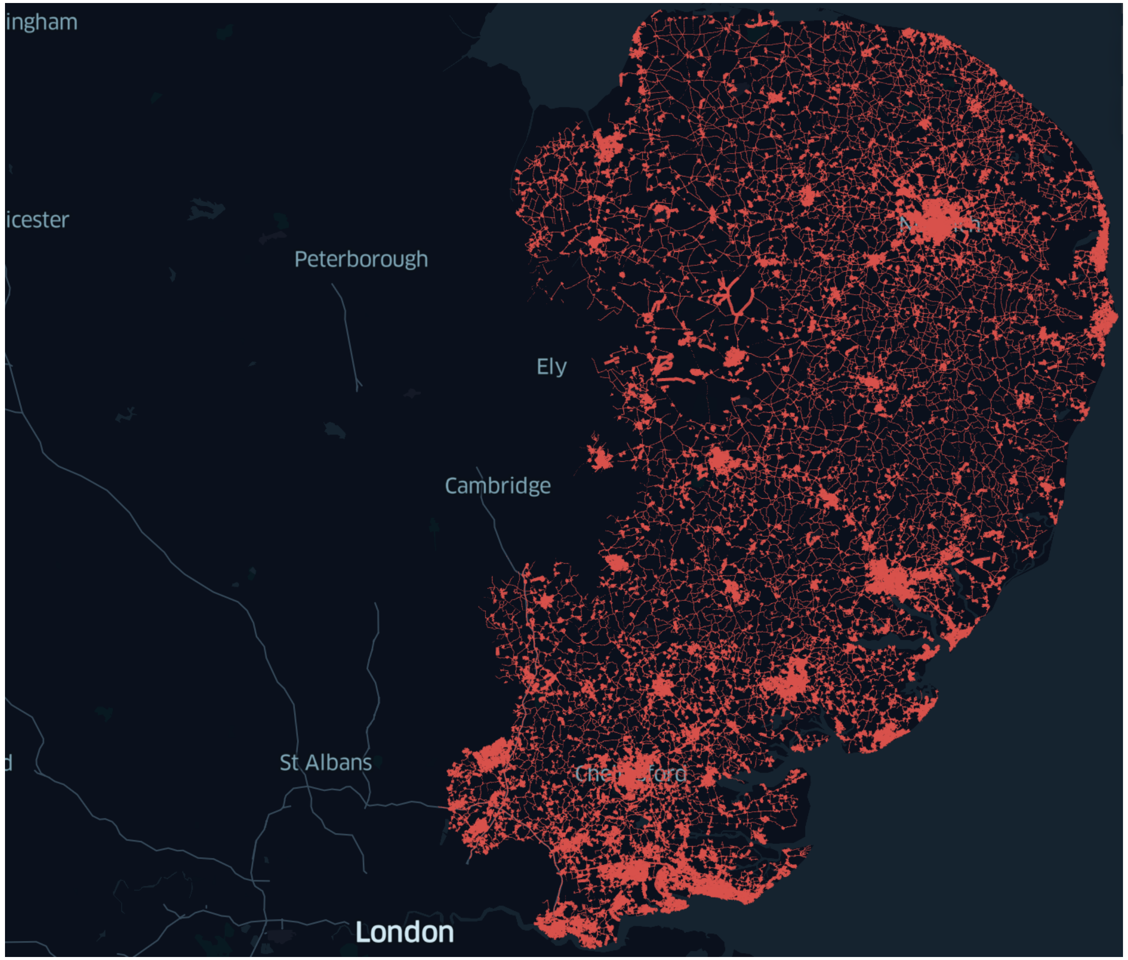
The granularity of the ABM allows us to look at carbon emissions in detail

The outputs of the model provide speeds for every vehicle trip in the model, at individual link level. This means that we can apply a set of emissions parameters to vehicle movement based on vehicle type, engine size, and fuel type. This allows us to calculate CO_2 equivalent emissions for every trip in the simulation and aggregate these spatially, temporally, and by agent.

This gives a much more detailed and useful insight into where, when, and why people generate carbon with their travel.

The following pages look at the overall carbon output of the region, with some breakdowns per vehicle type, agent attributes, and spatially.

As discussed previously, our 2040 population has different demographics, a very different mix of vehicles, and some changes to behaviours (including working from home). This increases demand in the region, without an equivalent increase in infrastructure, encouraging stronger growth in non-car modes.



2040 car emissions per km

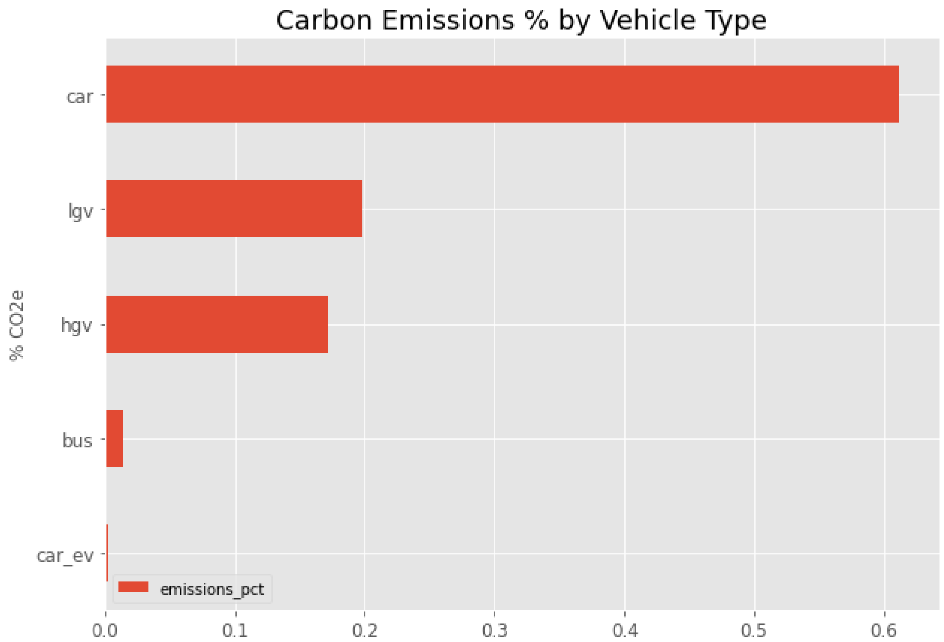
2019 Emissions

Emissions Insights

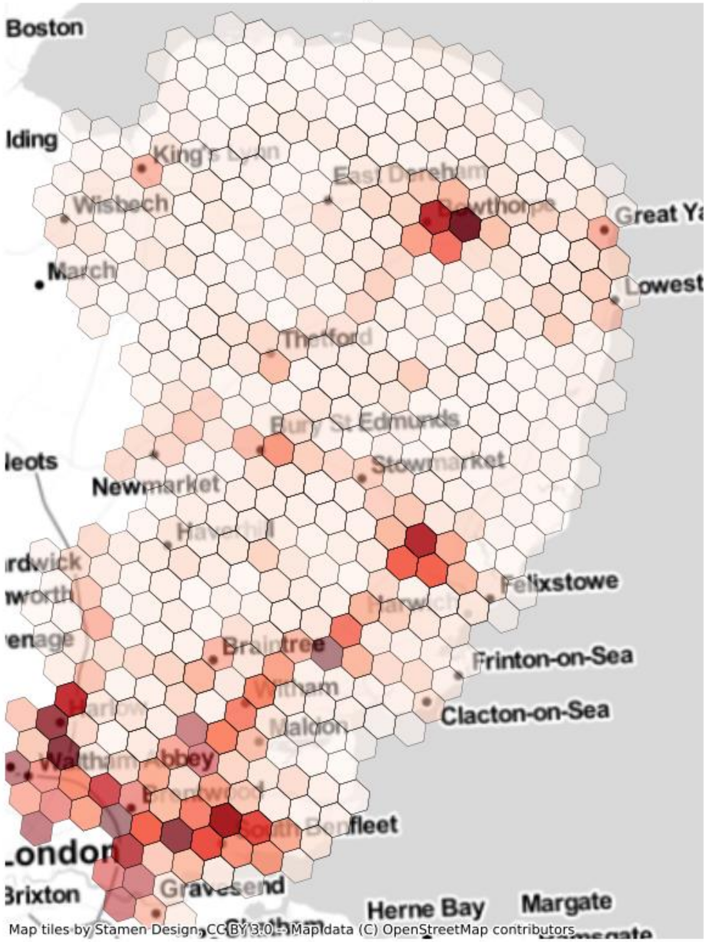
Before comparing the 2040 scenarios, we first measured emissions for the 2019 baseline. Spatially, emissions have hot spots closer towards London and in Norwich. Emissions are highest along the M11, M25, A11, A12, and A14. This is expected as they are part of the strategic road network connecting major town centres within the region.

For the vehicle types that we estimate emissions for (we exclude rail, subway, and active modes), we find that petrol car contributes 61% of total emissions (from 61% of trips, 62% of distance), and freight (HGV and LGV) contributes 37% of emissions (from 11% of trips, 14% of distance).

This highlights the importance of understanding the demand that drives freight movements and to seek opportunities to mitigate these emissions.



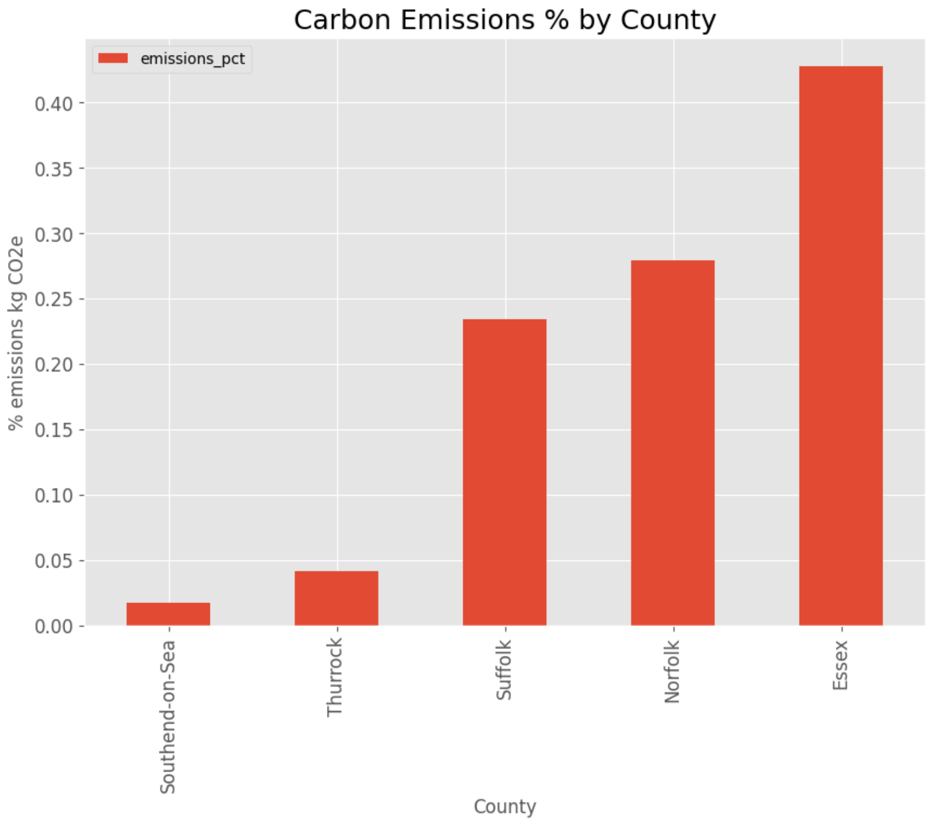
Carbon emissions, 2019 Baseline

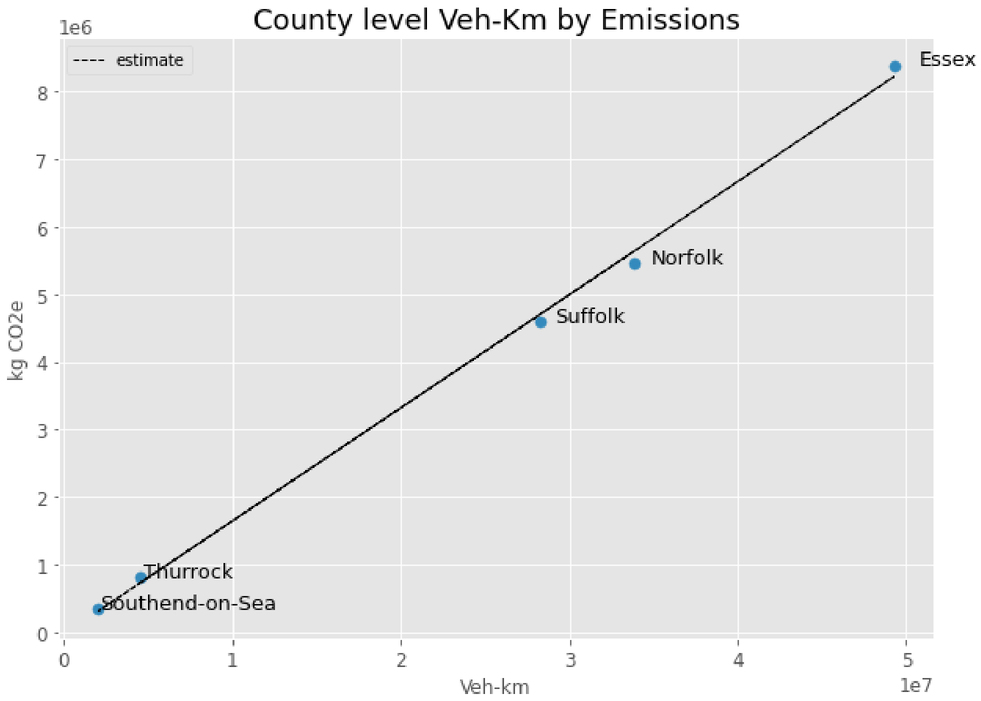


2019 Emissions

Where do emissions come from today?

Essex is responsible for the most emissions within Transport East (42.8%) and Southend-on-Sea contributes the least (1.76%). At a county level, we find that each county contributes proportionally more emissions as vehicle KM increases. The relationship between veh-km and emissions is not perfectly linear, and will depend on the levels of congestion and vehicle mix within each county. We look at the emissions by vehicle type for the 2040 scenarios later in this section.





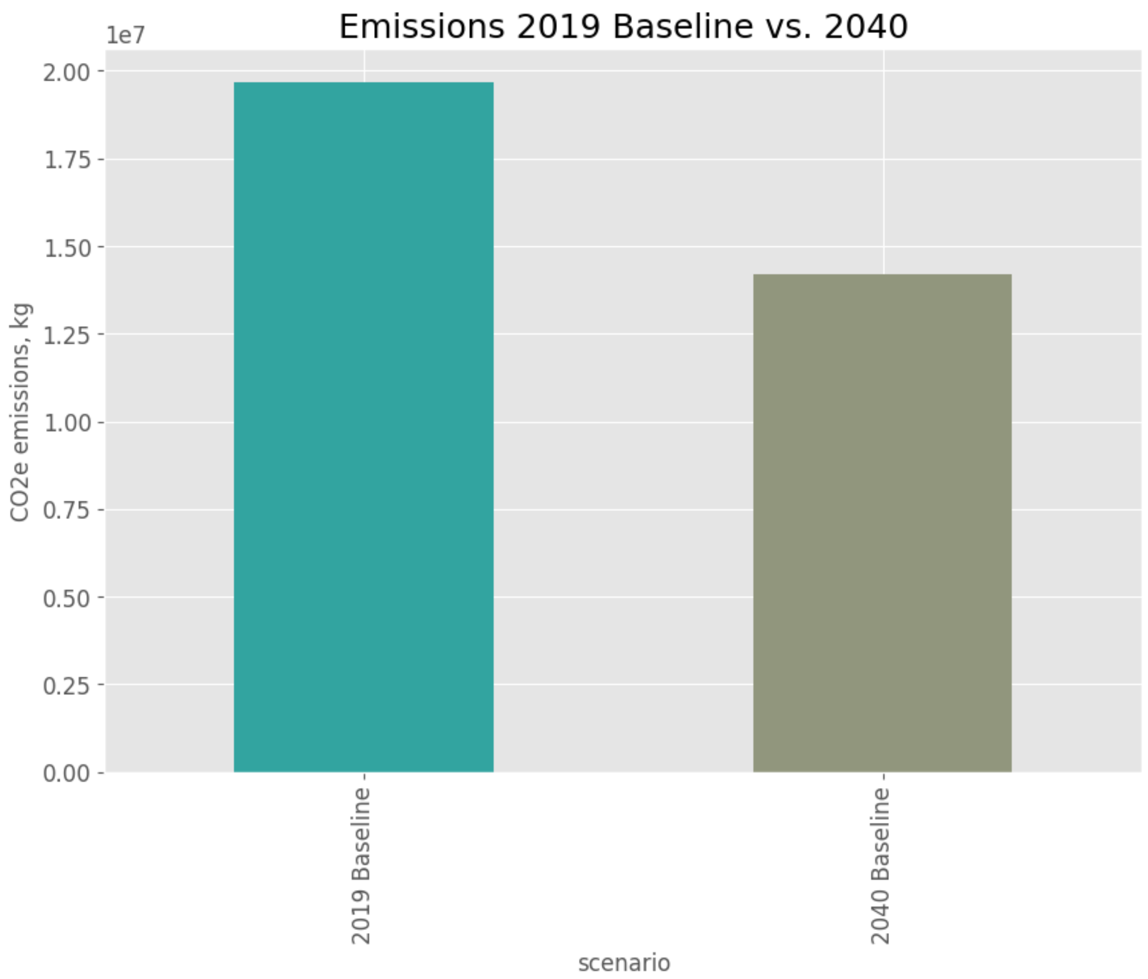
Carbon emissions: 2019 vs. 2040

Emissions Insights

When comparing the 2019 and 2040 baselines, we initially see a decrease in emissions. There are a few components of this estimate that should be considered, and more detail is available in the 2040 Baseline overview:

- In 2040, we have included an increase in work from home, which will reduce average trip rates across the model, along with emissions per agent.
- We have also anticipated an increase in EV vehicles which will reduce emissions for both private cars and LGVs and greater efficiency in petrol & diesel cars that reduces the emissions of the combustion fleet.
- Despite these changes, we still anticipate an increase in trips and vehicle kms due to population growth. Therefore, the anticipated increase in demand by 2040 will require decarbonisation policies to manage.
- There will be a change in WebTAG assumptions in November 2022 that will be applied to the 2040 estimate (details on following page). This will likely increase the 2040 emissions.

Overall we are happy that emissions are following expected trends within the baselines.



Total emissions by scenario

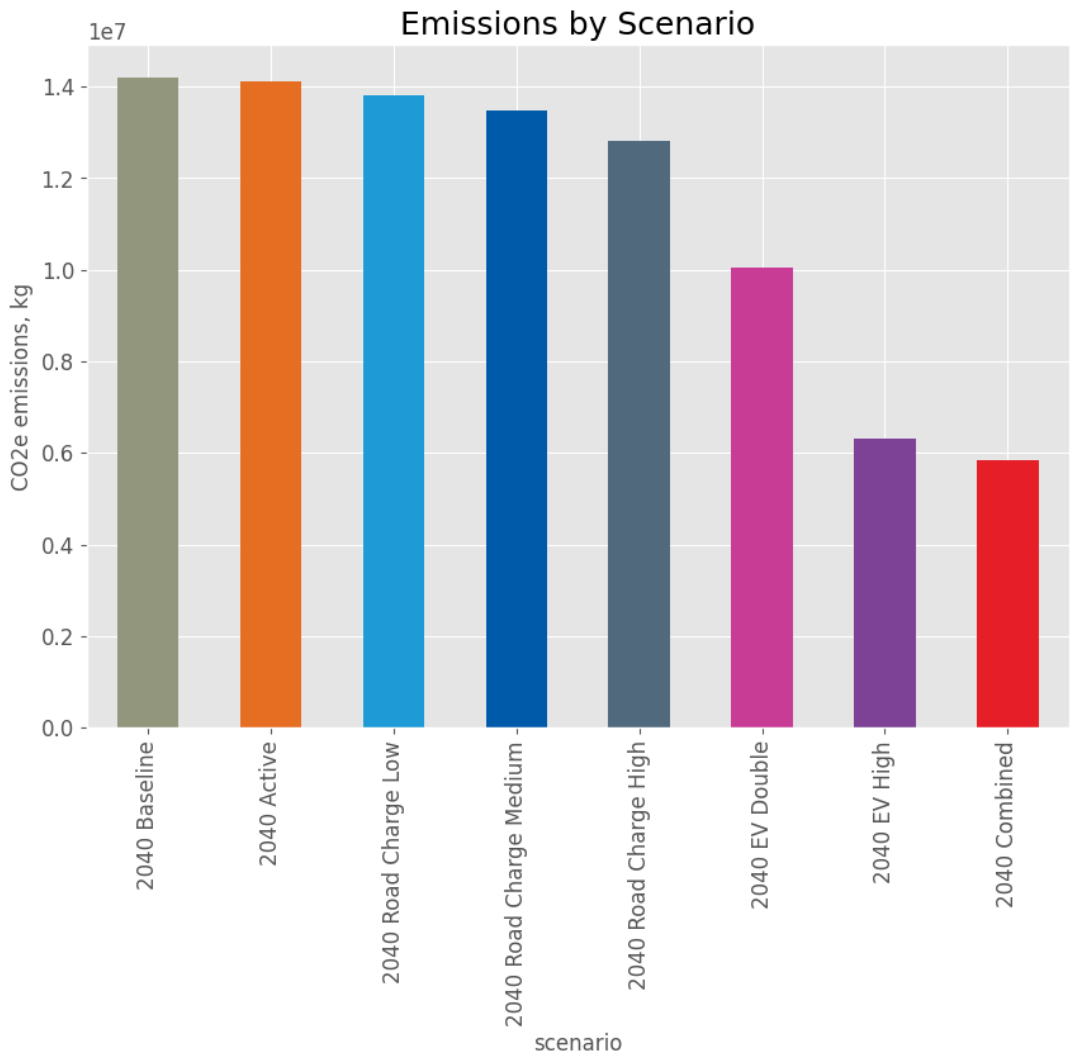
A note about emission analysis

Across all of our scenarios we see emissions decrease. As expected, the largest decrease is from the ‘combined’ scenario which contains high EV uptake and high road pricing.

Individual vehicle emissions estimates are based on the DfT's TAG guidance as of May 2022. An update is expected to be published in November 2022 which will change some of these fleet assumptions.

Currently, it is assumed there will be greater efficiency in petrol & diesel cars. The upcoming TAG guidance change will instead assume greater EV uptake and less efficiency gains in petrol & diesel. Bus efficiencies currently do not assume improvement through 2040, the November update will reflect efficiency gains.

Therefore, the absolute emissions estimates will change, but the differences and between the scenarios will remain largely consistent.



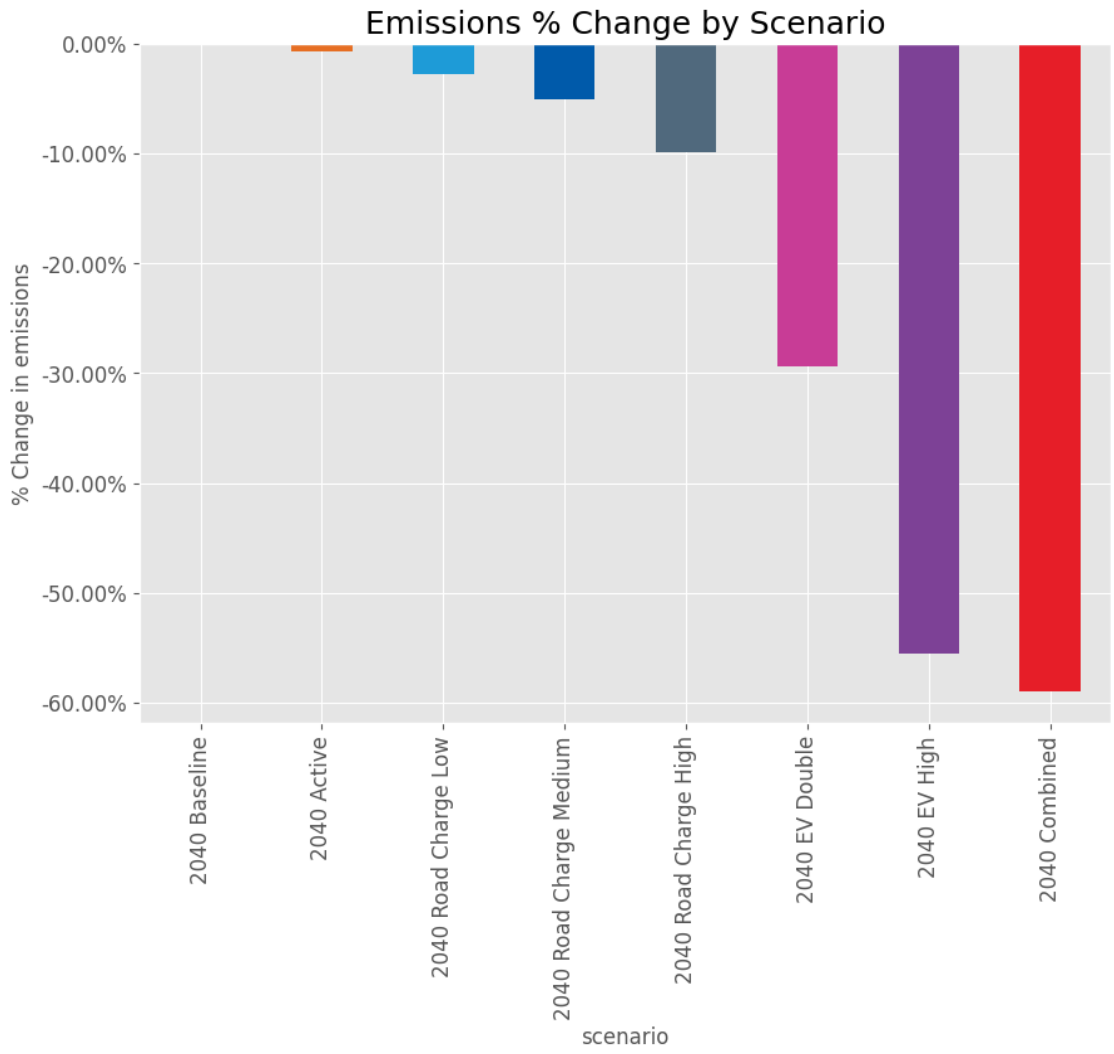
Total emissions change by scenario

We see non-additive effects for the different policies

The **2040 Active** scenario has the least decarbonisation impact of all scenarios, and **2040 Combined** scenario yields the greatest reduction in emissions. These are expected results as the active scenario doesn't impact any emitting vehicles, so all change is a secondary result of mode shift.

The improved emissions reduction between **2040 EV High** and **2040 Combined** is marginal, as the reduction in emissions from the high EV scenario are offset by the increase in car vehicle km due to the reduction in overall pricing as EVs are cheaper to run, even with the increase in road pricing. This increases the amount that people drive, as seen in the mode shift analysis for the EV scenarios which creates additional congestion and emissions from non EV.

Assuming the high EV transition is possible and price for EV use remains consistent with our assumptions, we are likely to see increase in travel distance.



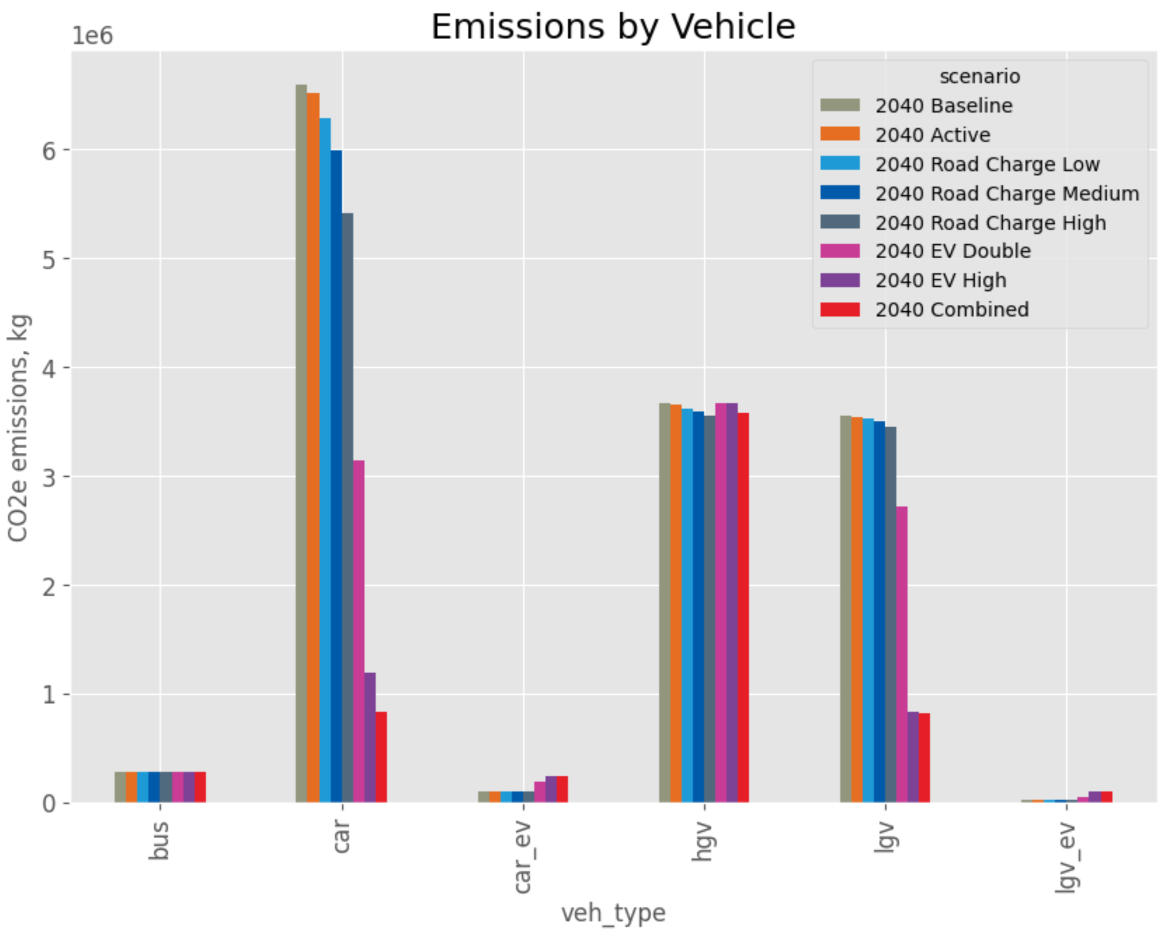
Emissions by vehicle type

Total emissions

The 2040 scenarios target a reduction in car emissions, with each scenario successfully reducing car's contribution to emissions. The introduction of more EVs into the household vehicle fleet should be a priority for reducing carbon emissions from the operation of the network. Emissions from car_ev and lgv_ev modes are associated with energy generation.

Emissions for both bus and HGV stay largely consistent throughout the scenarios as the ability to decarbonise these modes is much smaller, and assumed impossible for HGVs in the current scenarios.

A network with zero operational carbon would need to offset significant level of emissions under all of our scenarios.



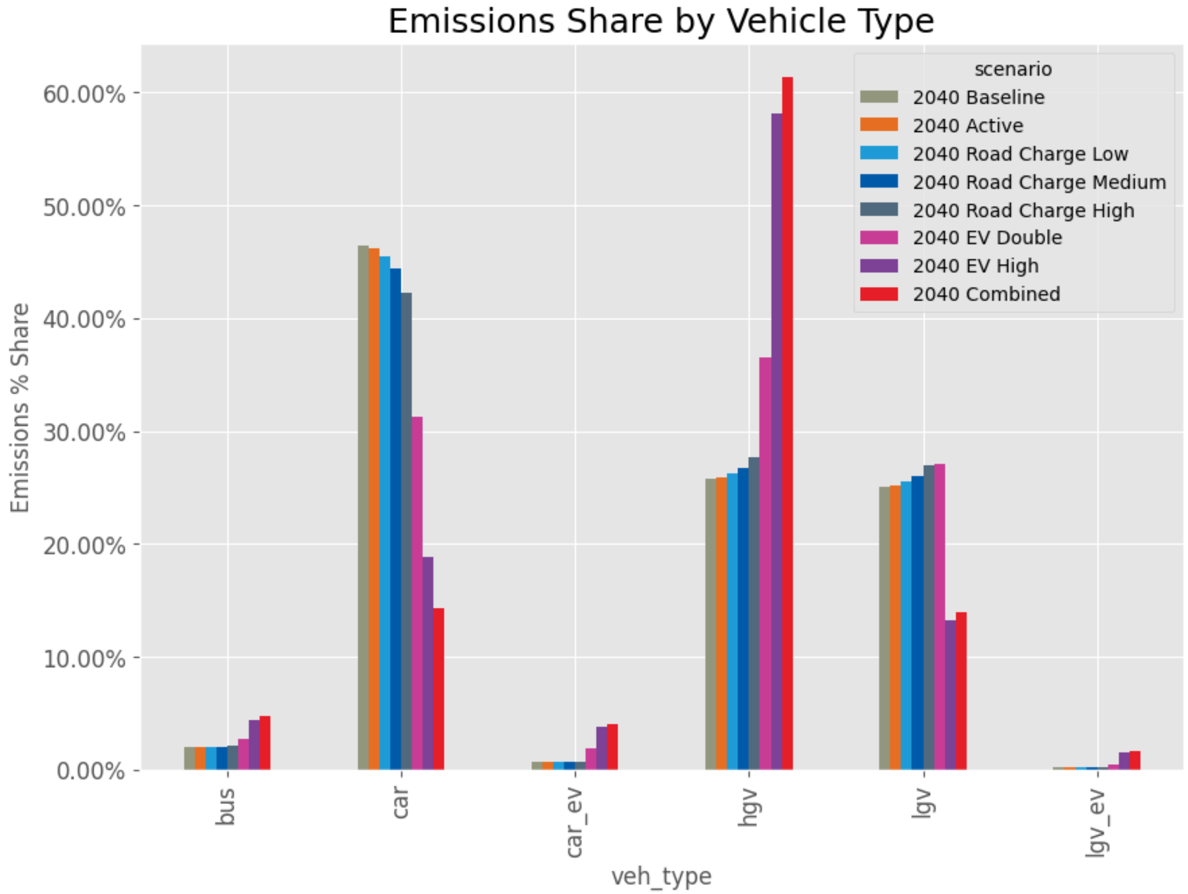
Emission change by vehicle type

Vehicle fleets need to be considered carefully

The adjacent chart shows a number of interesting outcomes for different types of vehicles. Firstly, the car_ev and lgv_ev modes show such high increases in the EV scenarios (including combined) due to the very low basis in the 2040 baseline. While EVs are much lower emitting, they are not zero, hence this large increase in fleet is responsible for most of the emissions rise.

The 2040 Combined scenario decreases car and LGV emissions by 80%. These are the categories that may change with the update to DfT emissions estimates as discussed on page 102. As noted on the previous page there is currently no trajectory in any of the scenarios for decarbonising the HGV or bus fleets.

Despite a two to three times increase in emissions for EV cars and EV LGVs, in absolute terms this is very small and the total emissions is significantly lower than the 2040 baseline.



Emissions Share by vehicle type

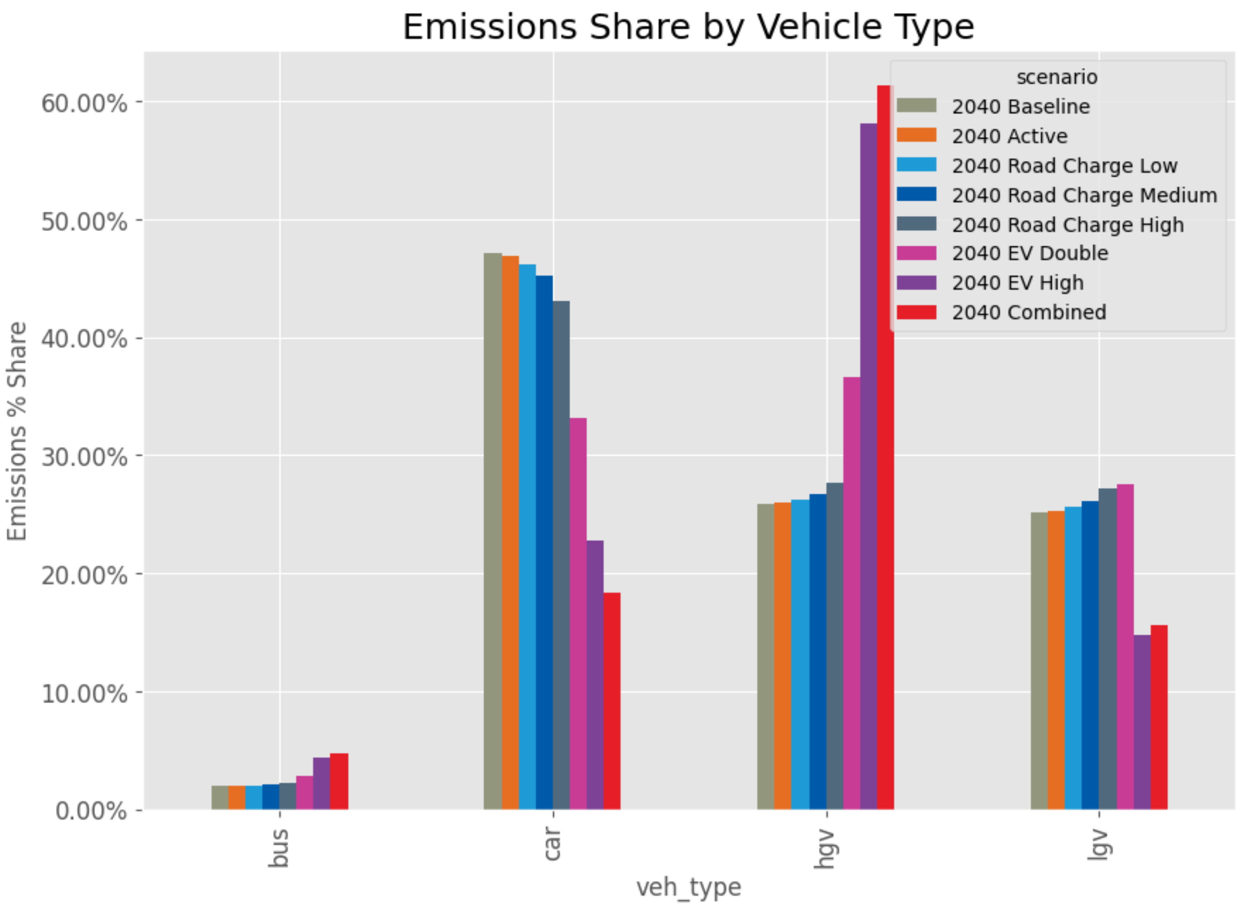
Emissions Share

For this analysis, we have combined the EV and combustion populations within the analysis.

As the share of emissions for car and LGV decreases across the scenarios, the share of emissions for bus, EVs, and HGV increase. HGV will have the largest share of emissions in the **2040 EV High** and **2040 Combined** scenarios.

Therefore, decarbonisation pathways that include an EV transition will need a solution for HGVs. This may come in the form of alternative fuels, consolidation, or mode shift to rail.

As EVs become the standard within the private vehicle fleet, freight becomes a bigger problem. At the moment, there are fewer potential ways to decarbonise HGV freight, and this looks to soon become the critical issue for decarbonisation in the longer term. This will likely require a combination of new technologies and carbon offsetting.



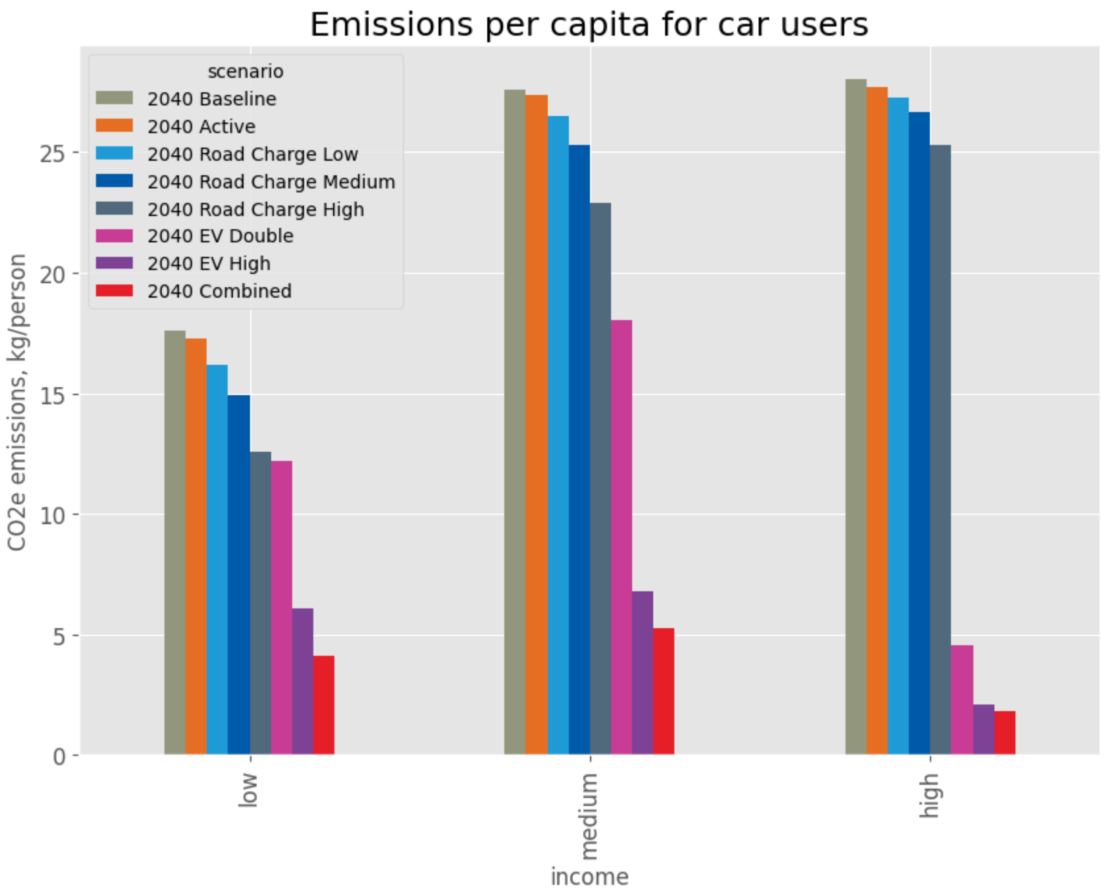
Emissions by income group

We see some interesting behaviour across income groups

By segmenting the emissions outputs from the model, we can see interesting behaviours related in agents' income group. Due to differences in the populations of the income groups, we look at emissions per capita.

The emissions per capita for both medium and high-income car users is approximately 60% higher than low-income car users in the baseline simulation. This is due to higher trip rates and longer trips for these categories

The high-income car users are most impacted by EV uptake and become the least emitting income group in the **2040 EV Double, High and Combined** scenarios. This is expected as our EV allocation assumes that EVs are more likely to be owned by higher income agents (see page 63)

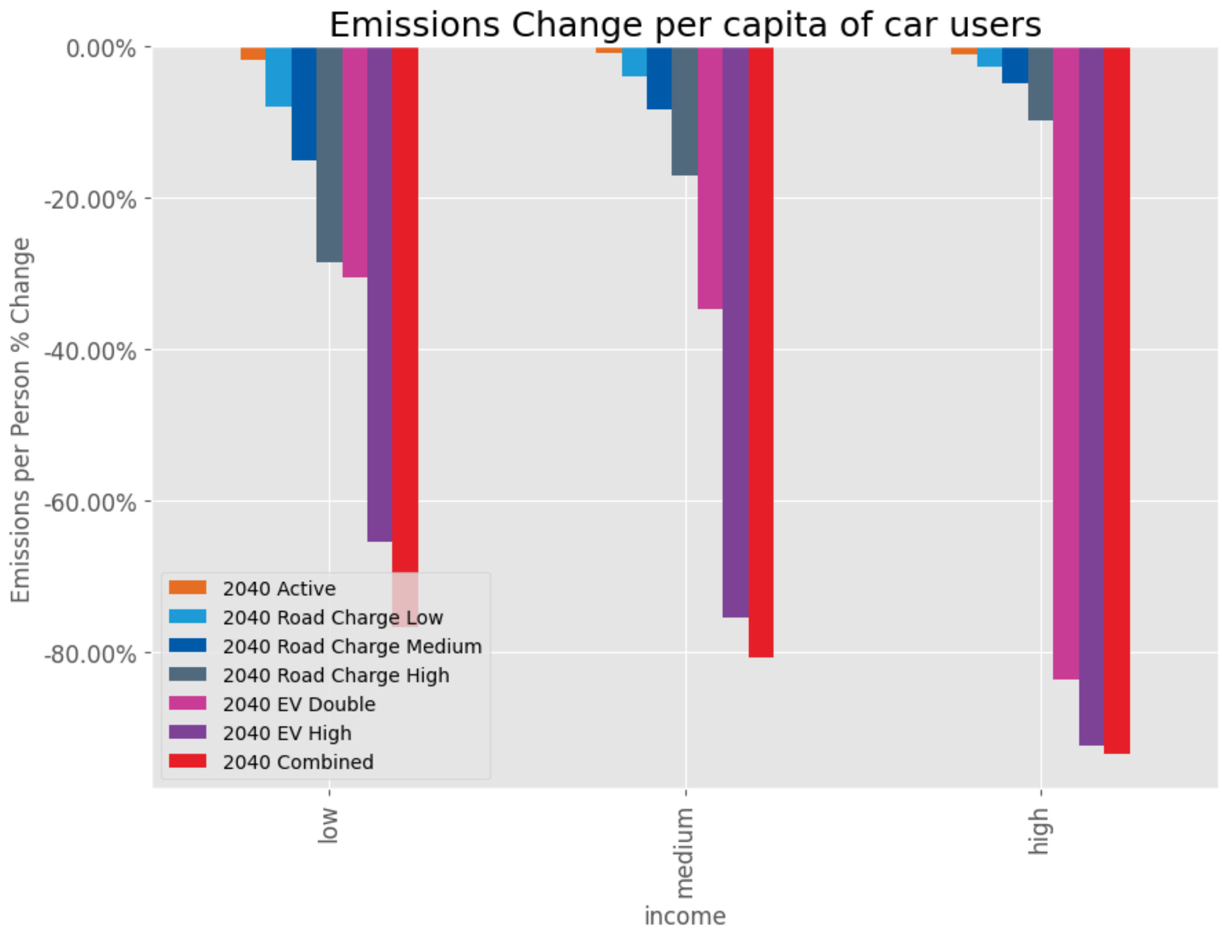


Emissions by income group

% Change per capita

Amongst the **Road Pricing** scenarios, low income car users have the greatest reduction in emissions per capita, indicating their behaviour change due to increasing costs of cars shifting them to public transport or sustainable modes. High income car users experience the least reduction in emissions per capita. It is worth contrasting this to the equity impacts and agent utility analysis, where low income agents suffer the biggest decrease in outcomes across all of the scenarios.

Amongst the **EV and Combined** scenarios, high income users experience the greatest reduction of emissions, up to 93% in the **Combined** scenario. This isn't associated with a similar loss of utility as experienced by the lower income agents.



Emissions Change

Emissions Change

Spatial distribution of changes

These maps show change in emissions for the high road pricing and high EV uptake scenarios. Green represents reduction in emissions, and red growth. Line width denotes magnitude.

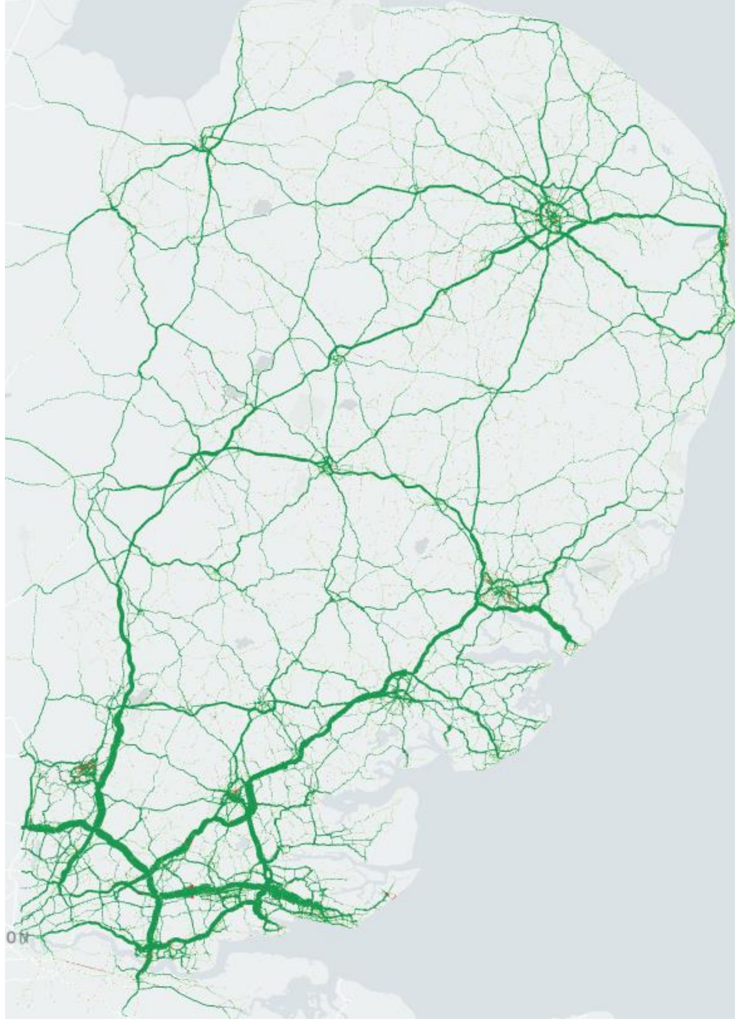
In the high road pricing scenario we see significant reduction on emissions along the Strategic Road Network (SRN), while the high EV uptake scenario presents reductions throughout the entire network.

This is due to the very high change in emissions profiles in the EV uptake scenario across the vast majority of journeys in the model. The emissions reduction in the high pricing scenario is more closely aligned to the SRN as a result of there being far more volume and vehicle km on those links.

For the active scenario, carbon reduction is, expectedly, concentrated in urban areas where short trips are more prevalent (plot not shown).

2040 Road Charge High vs. Baseline: CO2e difference

2040 EV High vs. Baseline: CO2e difference



Carbon: Insights Summary

Where and amongst whom do these policies reduce carbon the most?

What is the analysis: We discover insights on likely decarbonisation responses to EV and road charging policies based on a detailed analysis of the speed and vehicle type used in every journey.

Key takeaways:

- The combined scenario of high EV and road charging yields the greatest reduction in carbon. However, it is only marginally higher than the high EV scenario, as EVs encourage additional driving with the current cost parameters.
- Road charging primarily reduces emissions on the main roads, EVs reduce emissions throughout the network, and the active scenario has localised reductions in emissions closer to town centres.
- The proposed scenarios reduce emissions amongst cars and LGVs. HGVs, however, will grow in their share of emissions as alternatives are found for cars and LGVs.
- Amongst road charging scenarios, low-income car users reduce their emissions the most per capita, indicating a mode shift due to a higher sensitivity to costs and more negative experiences as a result of additional costs.
- Over the scenarios, high-income car users reduce their emissions the most amongst EV scenarios, demonstrating their ability to afford EV as a decarbonisation solution.

Further work:

- Segmentation of emissions reductions by different trip purposes and vehicle occupancy levels.
- Model the economic impact of different scenarios.
- Bus and HGV decarbonisation pathways, potentially looking at more complex fuel mixes including hydrogen

Insights: Equity

ARUP

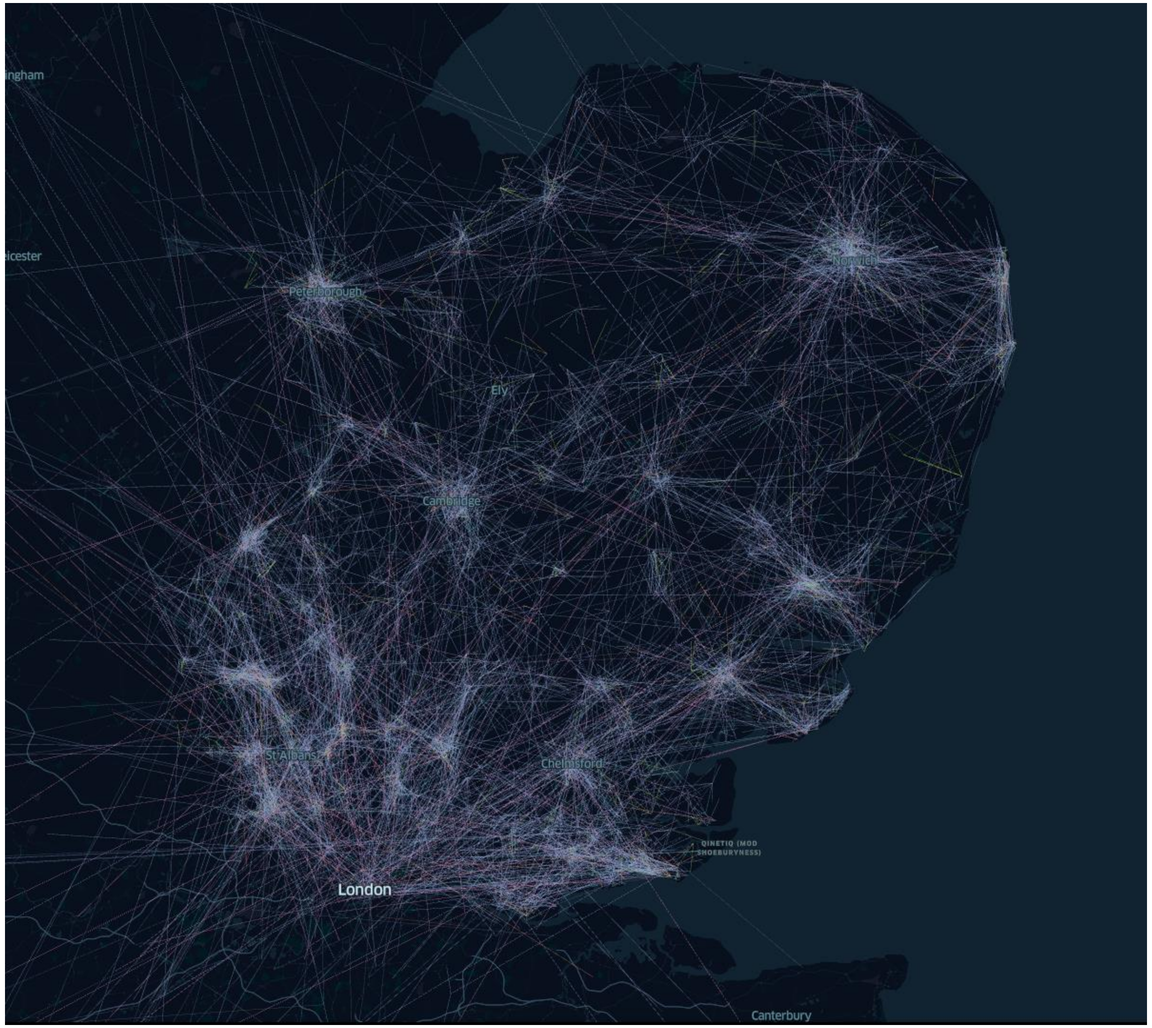
TRANSPORT EAST

Insights: Equity

How does people's experience of transport vary? Who is impacted by change?

'Equity' is about acknowledging that the same system will impact different people in different ways, and that there is no 'one size fits all' solution for many of the challenges facing us. People living in cities or those with higher incomes inherently have more choices as they can more easily switch between modes and adapt their patterns of activity in response to external changes. Someone on a low income, in a rural area with no effective public transport has far fewer choices and will be much less able to respond to changes in the future.

As we move towards a future transport network, complete with new technologies, modes of transport, and a lower environmental impact, we must strive for fairness as the impacts of policies become clear. The ABM, with its bottom up simulation of individuals with different attributes and behaviours allows us to really understand the impacts that will be distributed across the population.



Agent activity plans

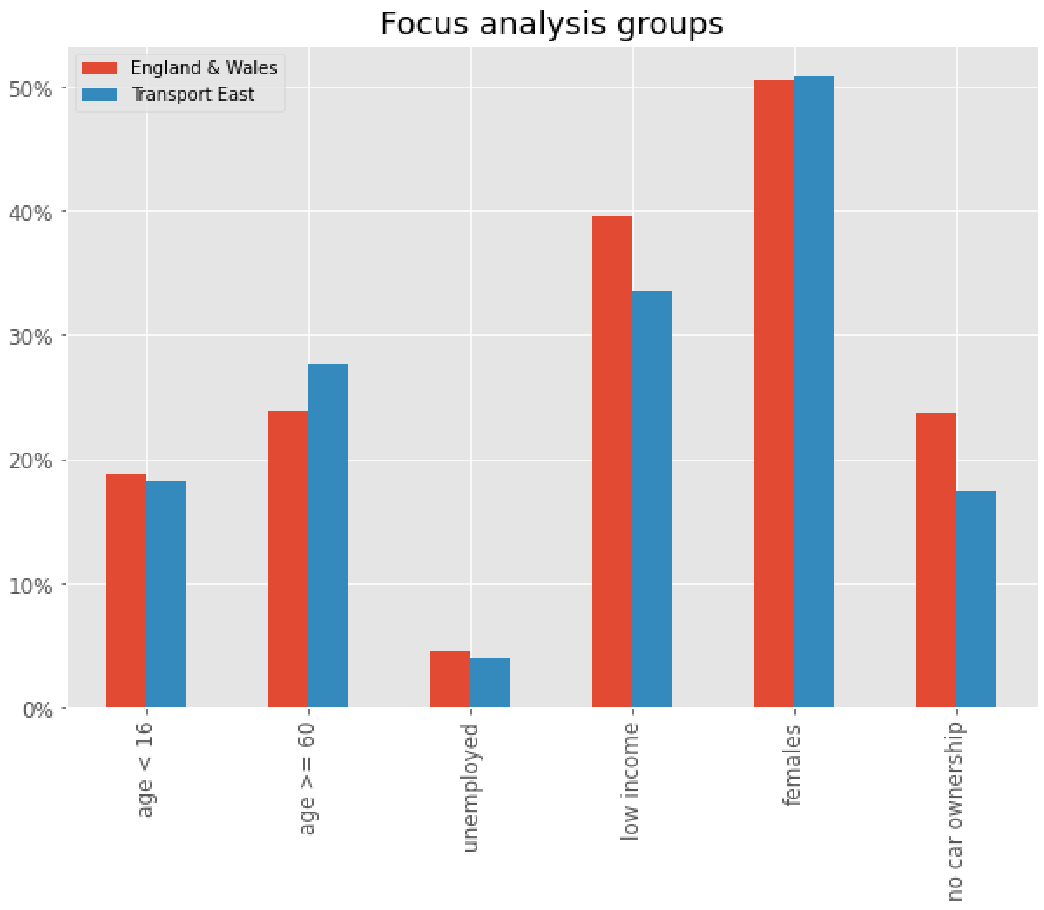
Insights: Equity

Equity in 2019 - Demographics

We compare baseline demographic distributions between the Transport East and country-wide averages, with the aim of identifying focus groups with regards to equity. We review some of the attributes that are often associated with transport inequality, such as age, gender, income, unemployment, and car ownership.

The Transport East area population is older than the average: it is characterised by a larger share of persons aged 60 years or over, and a slightly lower share of children.

The profile shows a relatively less economically-disadvantaged area when compared to the average statistics. It presents a lower share of low-income and unemployed persons, as well as a lower share of no car households. However, we are still interested in segmenting scenario outputs by economic attributes, as most of the scenarios directly affect the cost of travelling.



** income data are calculated at Region level*

Insights: Equity

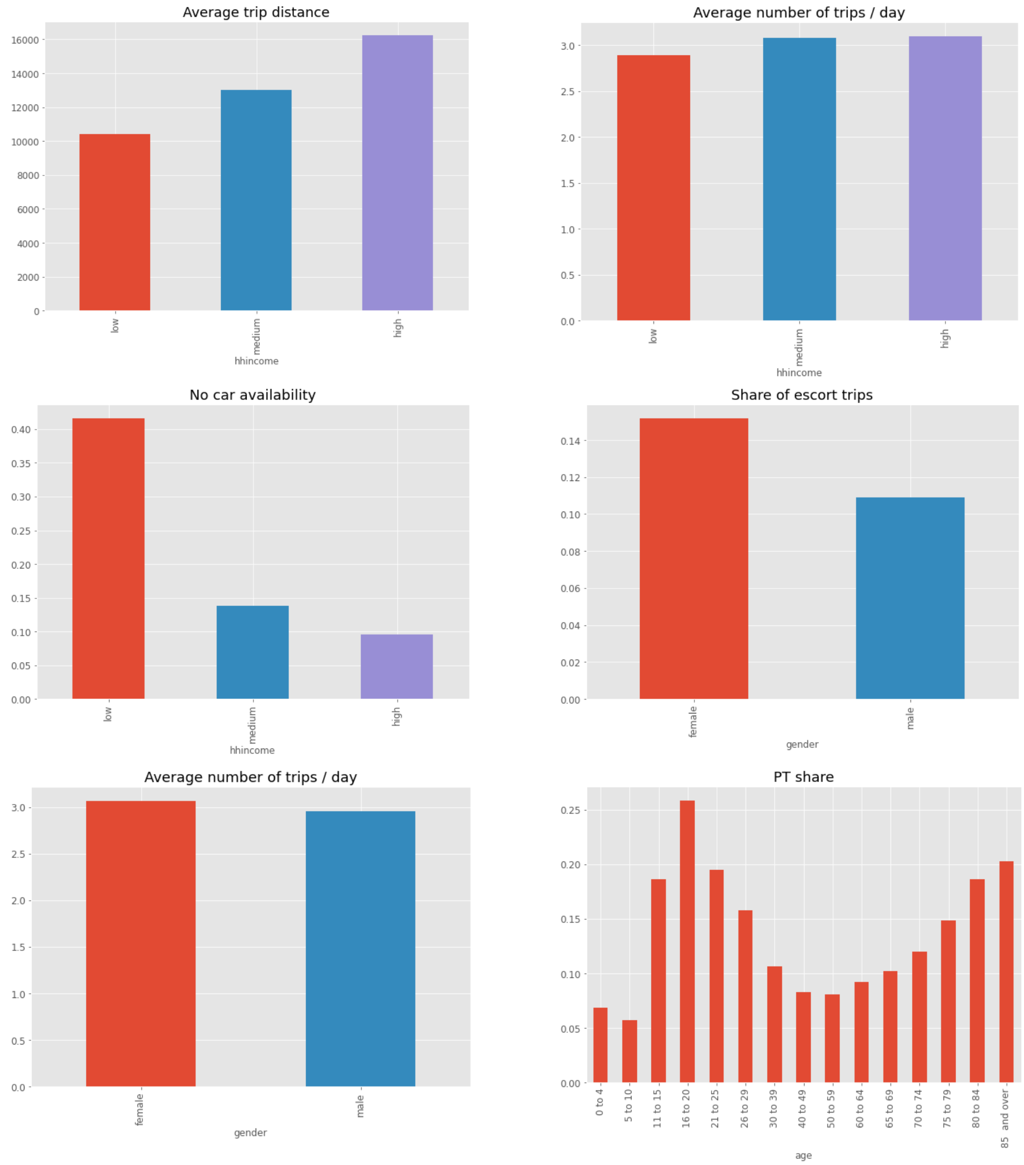
Equity in 2019 - Activities

The National Travel Survey dataset provides some insight on travel behaviour patterns of different demographic groups.

For example, high income groups are more likely to own a car, and they perform more and longer trips on average. Low income households have a much higher probability of being captive to public transport.

Females present relatively more complex travel patterns in the NTS dataset, with a higher number of activities within the day, slightly higher frequency of multi-modal tours, and higher percentage of escort trips. They are also more likely to use public transport or walk, but less likely to bike.

Younger- and older-age respondents tend to use public transport more. Younger ages show the highest share of active mode use. Older ages tend to make fewer trips, and present a different time profile compared to other age groups, with a larger share of trips happening during the inter-peak period.



Insights: Equity

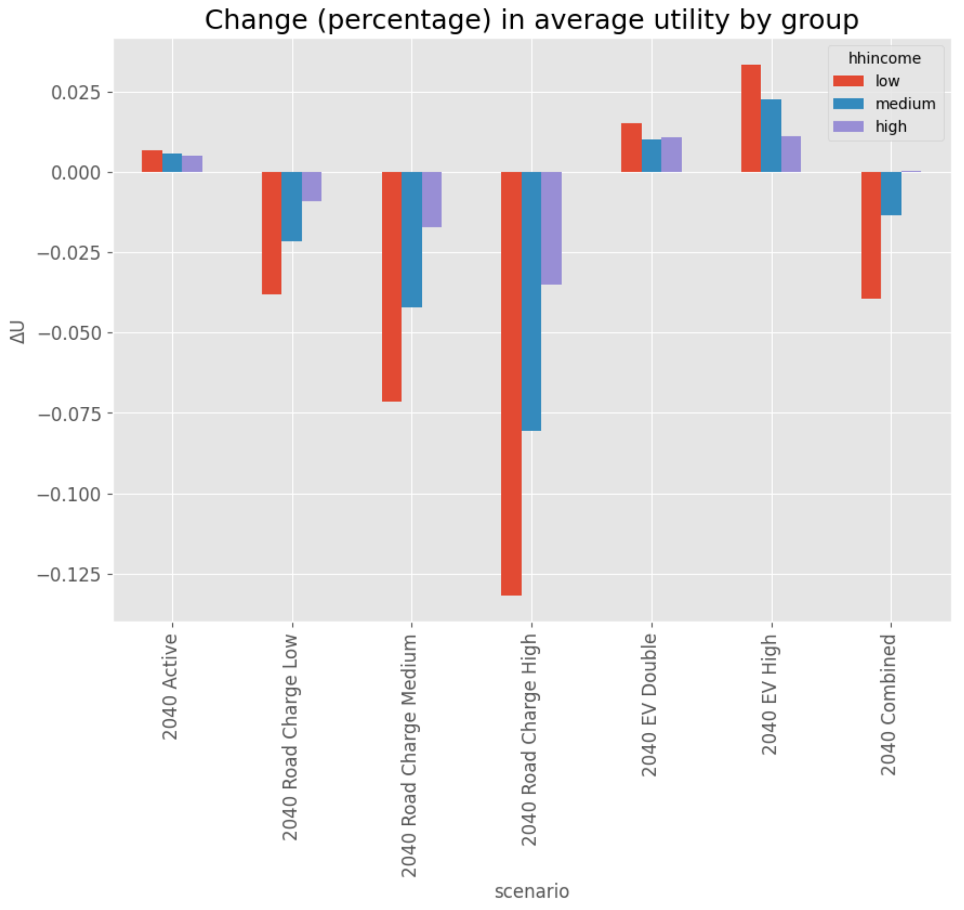
Income has some of the widest range of impacts

The chart plots the average change in utility for agents in different income groups, compared to the 2040 Baseline. We have three income bands in the population, low, medium, and high. These are assigned to agents during population synthesis using NTS data.

The active scenario is far more equitable, benefitting all income groups, and benefitting those of lower incomes the most. The EV scenarios also benefit all income groups. This is due to the reduced cost of EVs compared to combustion vehicles (assumption from the TAG Databook) and the dominance of car travel in the region. High income households are more likely to have an EV in our 2040 models.

The road pricing scenarios show a reduction in utility across all agent groups, and the largest drops in utility. The low income group is most negatively impacted due to their higher price sensitivity. We also see in the mode shift analysis that some agents are unable to use bus due to there not being enough capacity, and this is also impacting low income agents.

The combined scenarios shows a very small utility gain for high income agents, and a loss for low and medium income agents, reflecting the benefit that active modes and lower EV costs that benefit high income agents even in a scenario with high levels of road pricing.



Scenario equity impacts

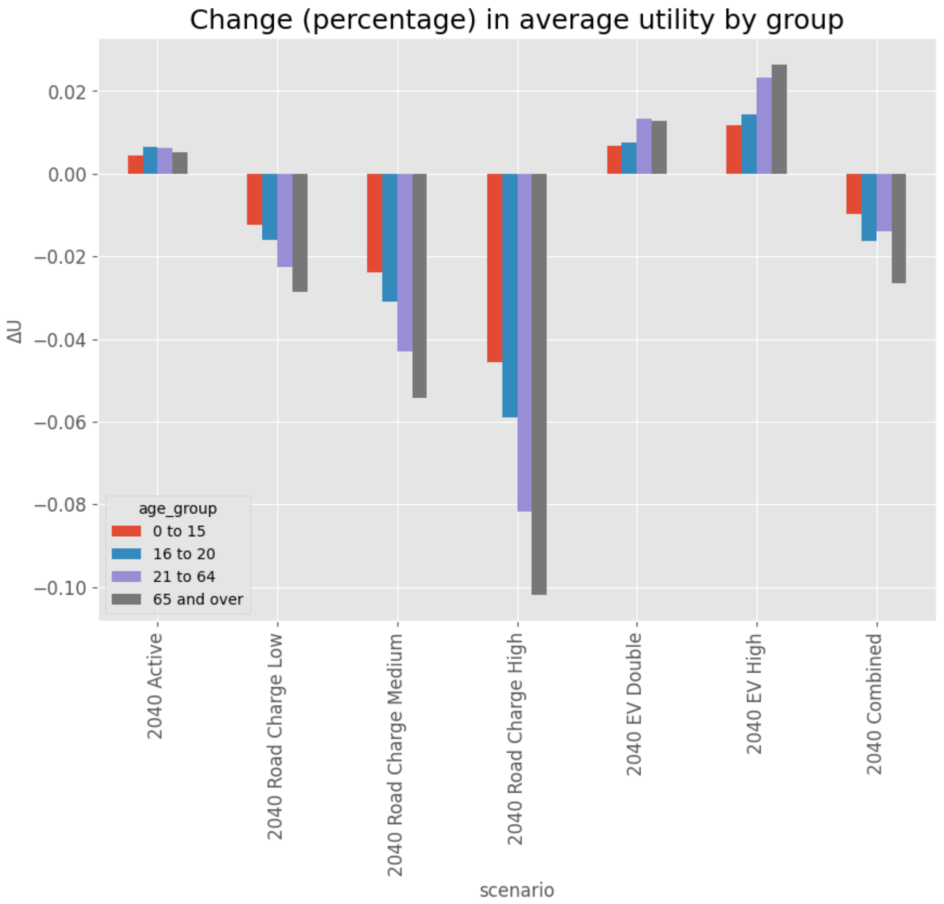
We see similar patterns of utility change by age, but impacts are worse for older people

Breaking down utility change by age group shows similar patterns in that road pricing reduces utility, EVs improve it, as does active travel improvements.

However, when we look at the impacts across age groups, we see that the older agents are, the more extreme their outcomes tend to be. Agents over the age of 65 lose out most under road pricing and the combined scenario, and benefit most from the highest EV scenario. This is especially interesting when we remember that the Transport East region is anticipating a more aging population in 2040.

These demographic impacts could come from a number of sources:

- Older age groups tend to drive more, and most of the utility shift in the scenarios impacts car users
- Different age groups are likely to have different activity patterns, with those over 65 likely to make fewer trips (and therefore have a higher impact for a single trip)
- Correlation with income. Investigating this along with other demographic correlations may be valuable future work.



Scenario equity impacts

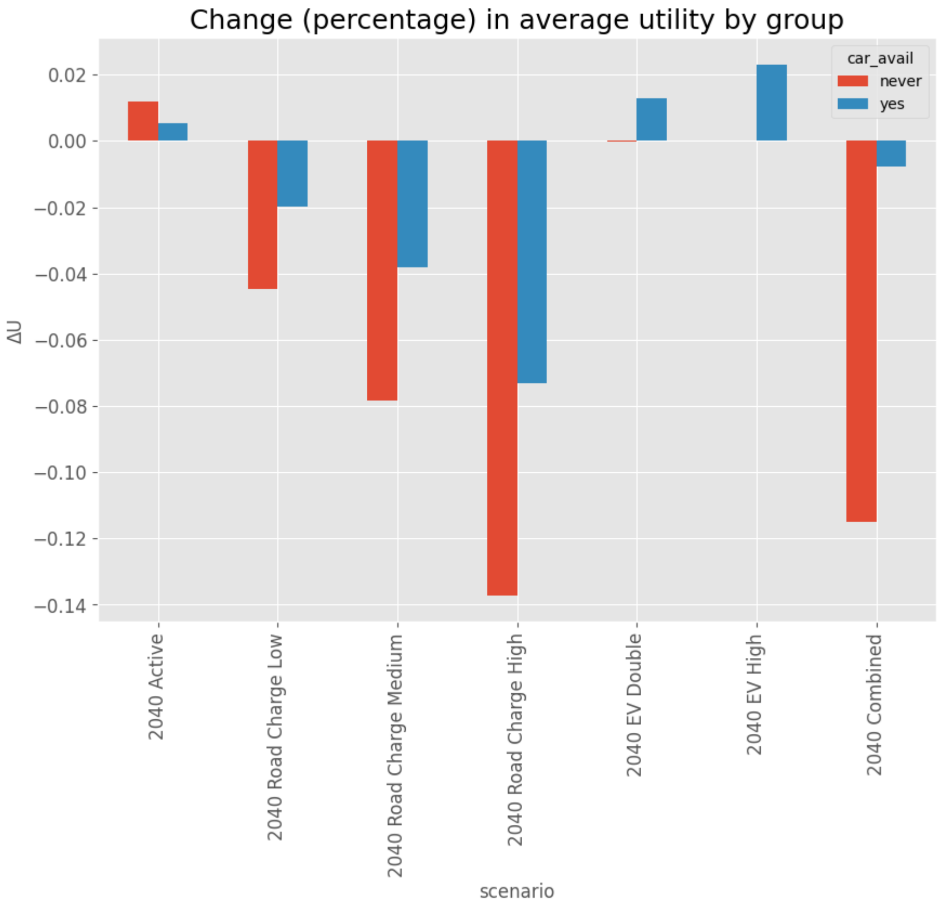
Households without a car have a limited choice set.

Within the population we mark each household as having access or no access to a car. This limits their modal choices, while a household with car_avail set to 'never' can drive, costs are increased significantly as these are assumed to be taxi journeys.

As expected, the EV scenarios only benefit car-owning households. The active scenario also benefits those without cars more as they are more likely to use active modes.

No car households are adversely impacted by the road pricing scenarios. This is initially counter intuitive, but this is from two sources. Firstly, portions of the PT network are operating at capacity and therefore some low income users who are reliant on PT in the baseline are unable to complete their days as they cannot board a service. Secondly, non-car households can use cars but pay a 'taxi' price premium which will be increase with other road costs.

There is also a likely demographic correlation here, as households without access to a car are more likely to be of a lower income group that have a greater reduction in utility.



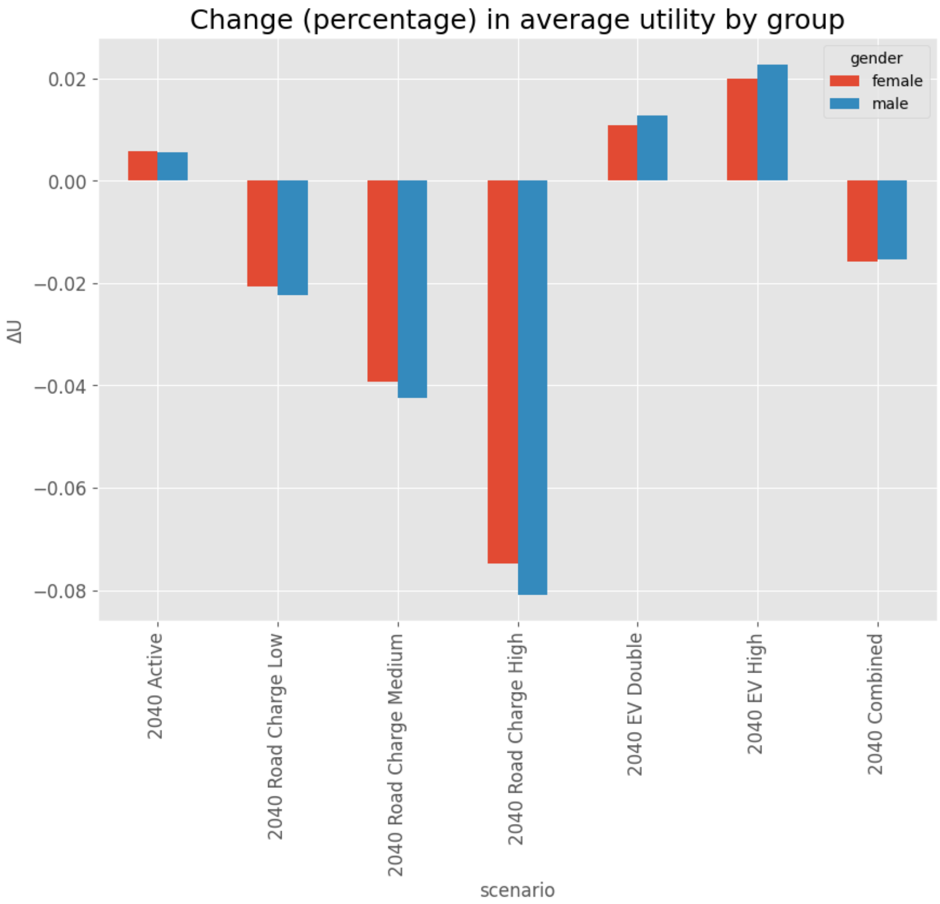
Scenario equity impacts

Impacts are less pronounced between genders

Across all scenarios, the difference in the utility change is least pronounced looking across gender categories than it has been in the previous analyses.

From previous models, we know that women tend to have different trip patterns to men, with more escort trips and a larger amount of trip chaining. This tends to make their days more complex from a travel point of view, and reduce down their options for innovation. Women benefit more in the active scenario and their more complex trip chains will benefit from cycling as it is not constrained by stops or services.

Road pricing and EV impacts are relatively higher for males. This is likely related to car use intensity and trip lengths being longer for men. Interestingly this is reversed in the combined scenario, with females marginally worst off.



Equity: Insights summary

All impacts in the scenarios are distributional,

What is the analysis: We look at how different scenarios impact different sub-populations of agents with different attributes.

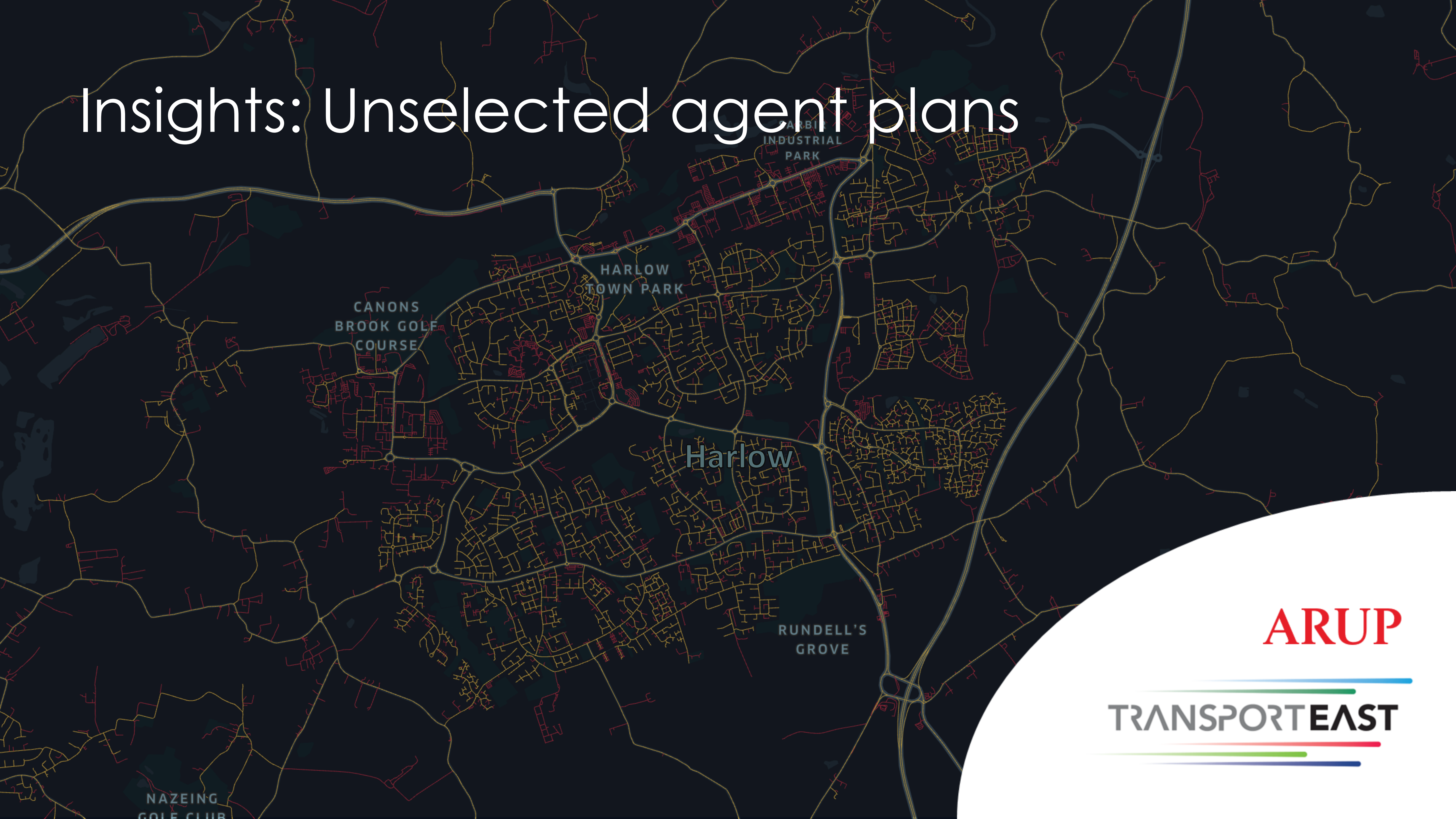
Key takeaways:

- An agent's age and income will mean they will have very different experiences of the same policy changes.
- Income seems to be the biggest determinant of how much an agent will see their utility change, with lower income agents likely to be less able to adapt to change without impacting their utility. Older agents also tend to suffer greater detrimental impacts.
- The active travel scenario benefits all, and while this is a small impact, it speaks to the lack of downside with improving the utility of active modes.
- Road user charging has a negative impact on all demographics, this is greatest for low-income households and the elderly. A flat per km road user charge could therefore have significant implications for Transport East residents and any road pricing needs to be introduced with care
- Our scenarios predominantly impact car users, so it is no surprise that this is reflected in the no-car households.
- There is a lower disparity between the genders that was initially expected, potentially due to the range of interventions that were simulated in this study.

Further work:

- Looking at how different agent attributes correlate with one another can help us understand more about distributional impacts.
- Enriching our population with more attributes (e.g. rural vs. urban, more granular income bands) will enable more analyses, but will require more data.
- Testing more complex and combined scenarios that are targeted to benefit different segments of the population (e.g. differential pricing by attribute).

Insights: Unselected agent plans



Synthetic Experience Extraction

What did agents choose not to do?

With every iteration, agents innovate; they can change their mode, their route, and perform some limited time of day adjustments. Over time, they find better plans as they experiment and learn what is successful.

We simulate hundreds of iterations and in each iteration some agents try something new. We generally care about what agents decide to do in the final iteration, as this should be their 'best' travel choice. But, what they choose not to do can also be very insightful. We may analyse these unchosen plans to understand their behaviour. We call this analysis Simulated Experience Extraction (SEE).

Methodology

In a simulation, an average agent will have tried around 100 plans and each of these plans has differences. We retain records for each agent's top 5 plans, including their overall utility score. The variation in utility score and transport decisions in the top 5 options tells us a lot about the choice those agents have in their daily planning. For example, we can see instances where:

- All plans are very similar, suggesting limited choice. For example, the innovations are only time based
- The plans are all very different, suggesting an agent has many ways of achieving their day. For example, changing mode, route and/or time

The diversity of their available choices tells us about their options more generally, and the variation in utility tells us how quickly an agents day worsens if they cannot make the preferred choice

Analysis

Within this section we provide a range of analysis to gain insights into what the unselected plans tell us about agent behaviour within the region.

For this analysis we consider the 2019 Baseline, 2040 Baseline, Combined, and Active scenarios. As with all of the analysis of the model, It is possible to further refine or focus this in future.

2019 Baseline: Plan utility

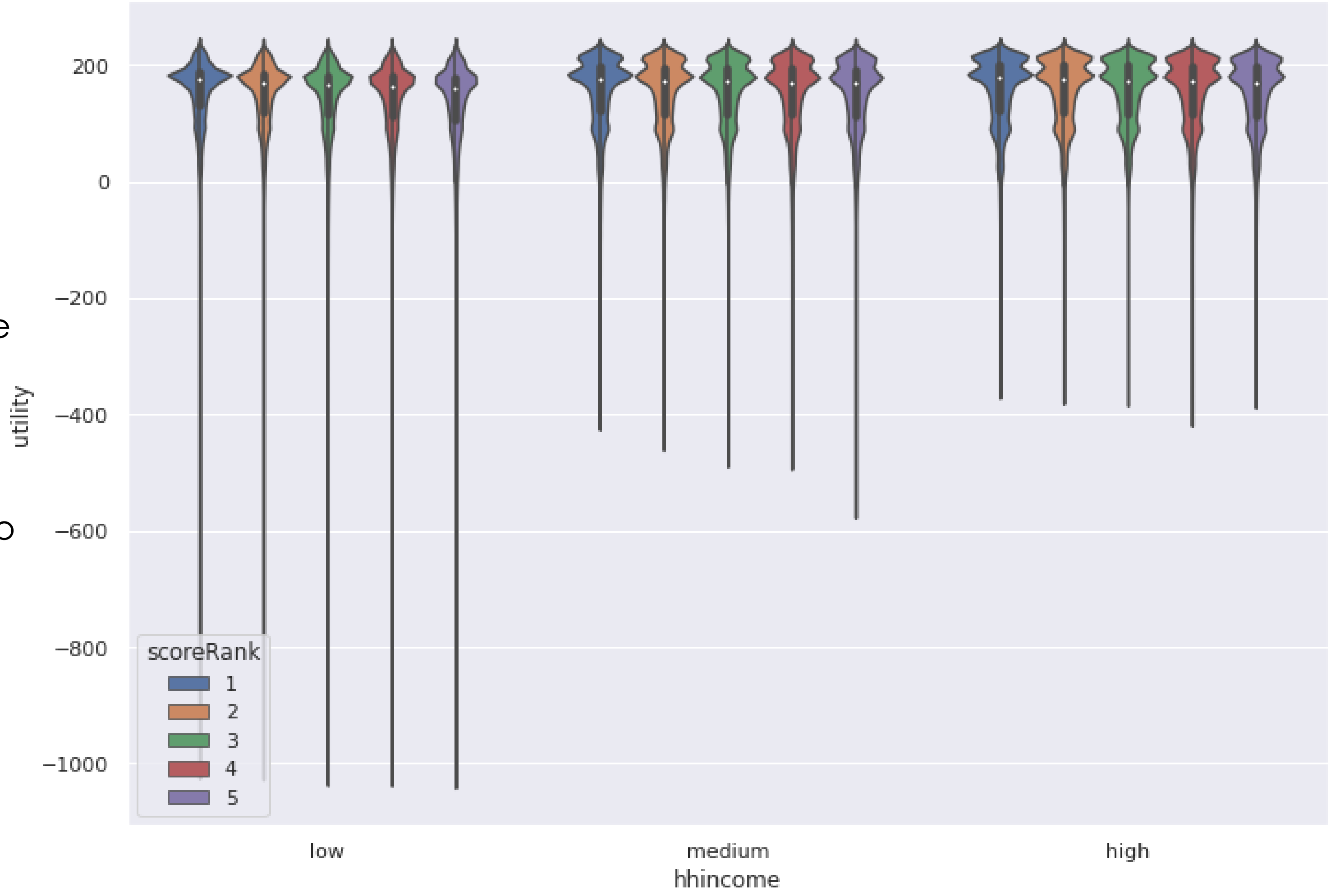
Utility box plots – the top five plans for different income groups

The violin plot presents the distribution of utility scores across an agents 5 plans (scoreRank), per income group (hhincome).

Simply, we can see that average utility across the top five plans is very similar, which is positive in terms of simulation stability.

Looking across the income groups, we can see that each has a different distributions of plan utility. High income groups have a smaller range of utilities than medium, and especially low-income groups. This suggests high income groups have more resilient choices available to them, with even the 5th ranked choice plan offering similar utility to the 1st choice.

In the low-income group, plan 5 has a reducing level of utility which can be seen by the narrower distribution body and increased tail towards 0.

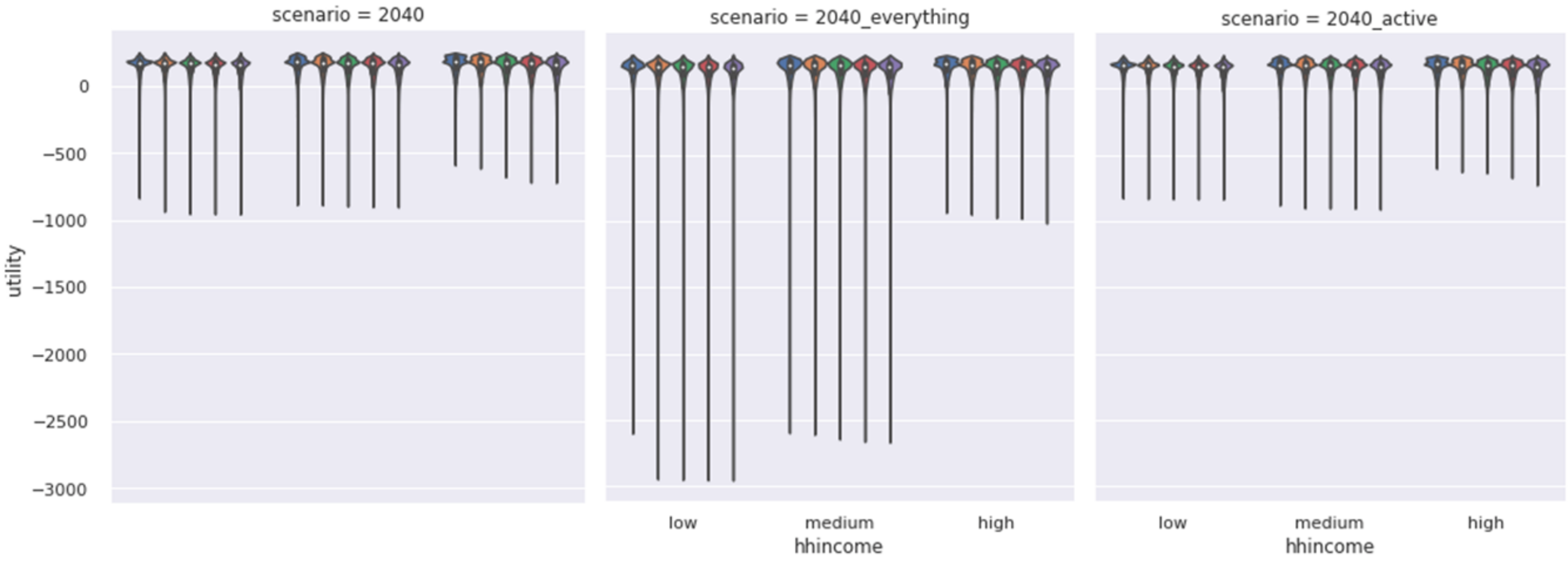


Comparing scenarios: Plan utility

What happens to utilities for the 2040 scenarios?

These are the same plots as the previous page, but looking across the 2040 combined (everything) and active scenarios.

We see that most agents maintain positive utility but many experience extreme impacts to their utility, stretching the distribution to wider ranges and creating a larger gap between winners and losers. The combined scenario is primarily responsible for stretching the range of utilities.



The spread of utility in the 2040 Baseline is similar to that in 2019, however the number of agents with low or negative utility starts to increase. This is likely a result of increased congestion on the network for car drivers with few alternative options. The active scenario, shows it offers little impact on the spread of utility scores for agents.

The active scenario generally improves utilities for agents, but this benefits medium and high income agents more. The interesting insight here is that the combined scenario increases the range of utilities for all agents, implying that there is less resilience in the combined scenario for non-high income groups.

Comparing scenarios: Mode shift

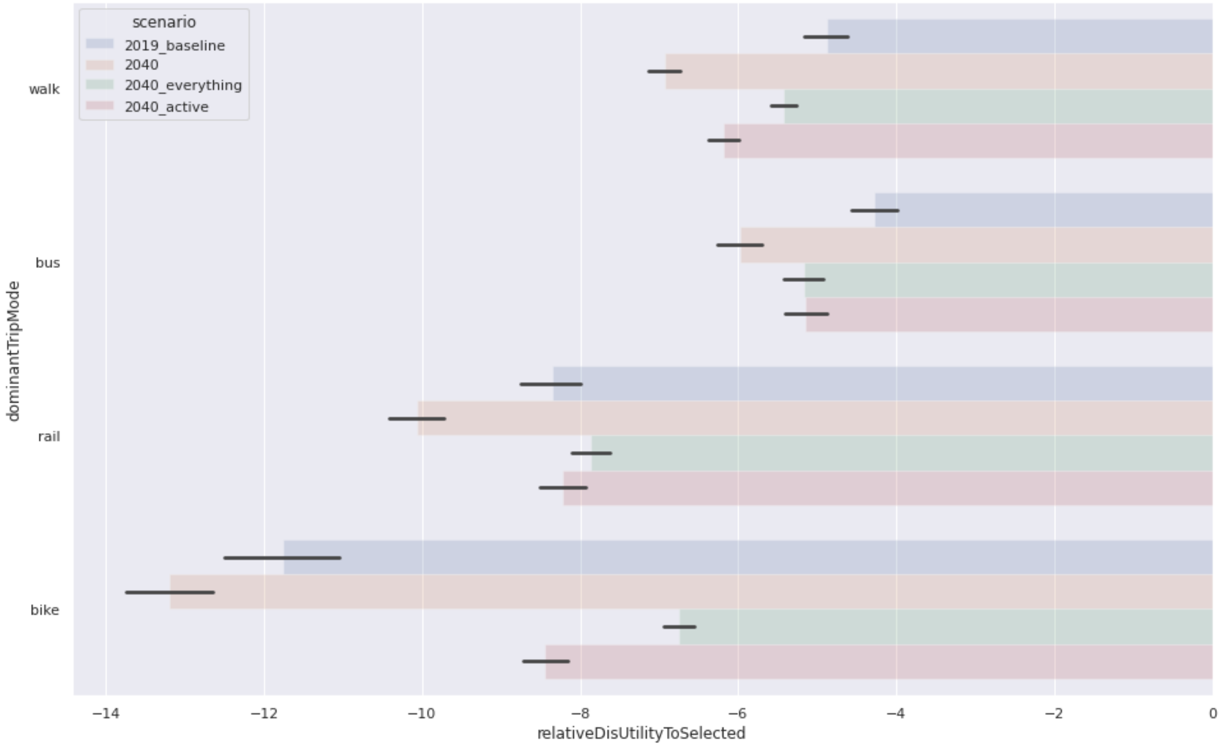
Can utility comparison show us which modes are most competitive with car?

This plot considers agents whose best plan was car based (car as the longest mode by distance). We then looked at their unselected plans to see how much worse the utility was, and aggregated by the alternate mode.

This shows us how close a non-car mode is to displacing car for the top spot. The bar chart presents the average disutility per mode, across the different scenarios.

Walking and bus exhibit the closest relative disutility, with similar scores across the 2040 scenarios. Albeit these average disutilities are further away than in the 2019 baseline (suggesting the gap has widened on average by 2040). Essentially bus and walking offer the closest utility to car, and should be the focus for mode shift initiatives.

Rail is shown to generally be consistent, and cycling is very diverse, depending on the scenario. The active mode scenario shows the expected behaviour as we modified its utility as the input.



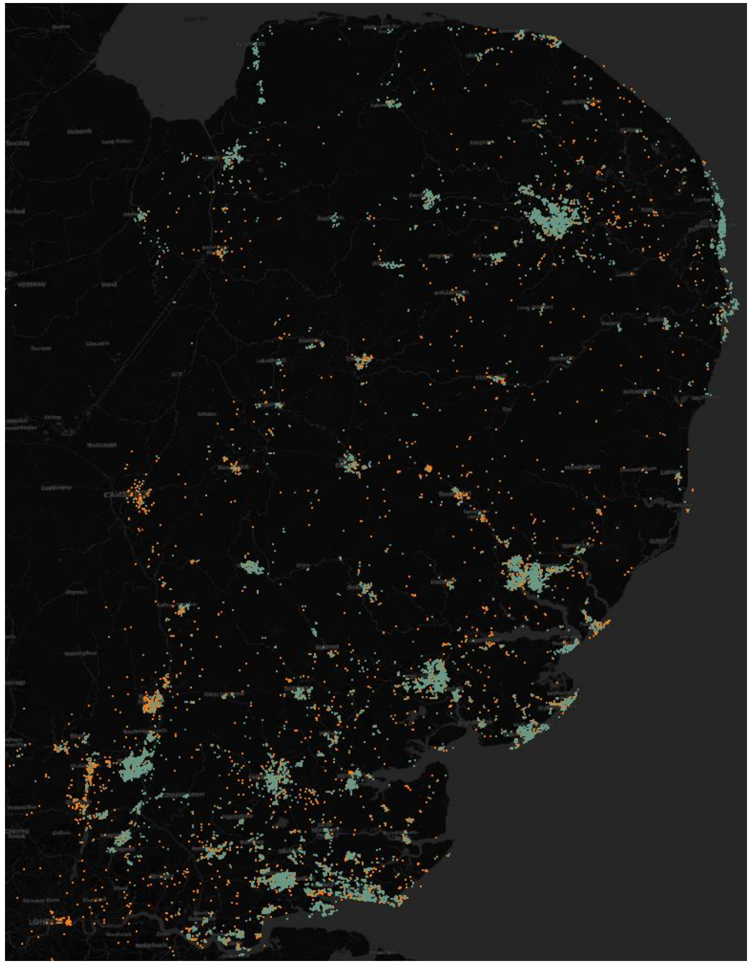
Comparing: Alternative PT plans

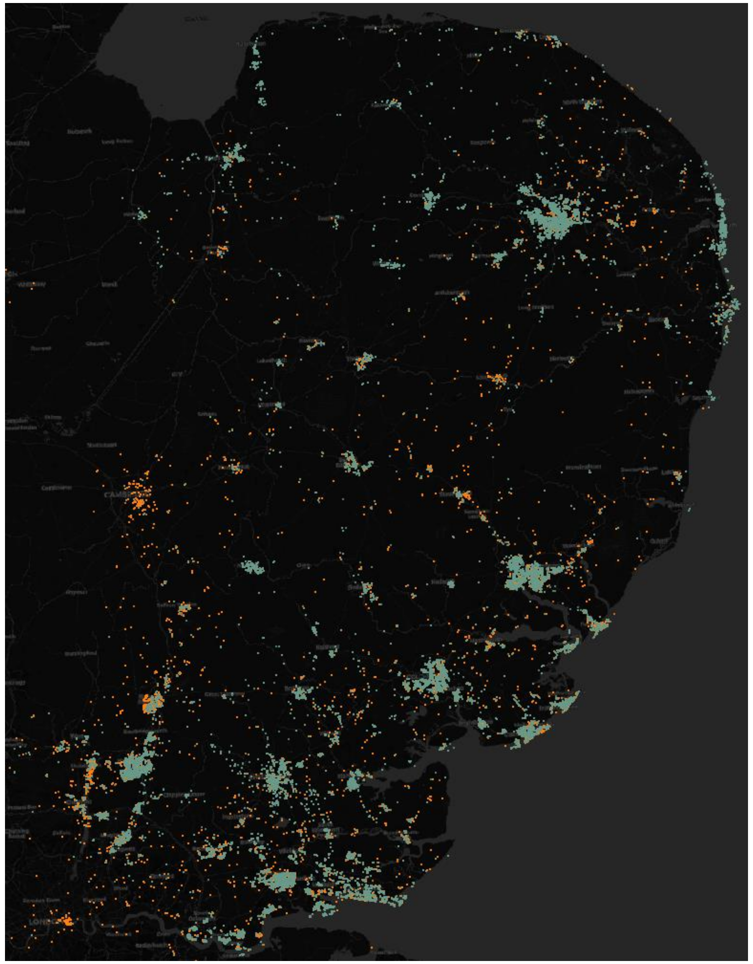
Spatial patterns of alternative plans

This replicates some of the first, exploratory SEE analysis undertaken for Suffolk. Here we look at car journeys where there was a public transport plan in the unselected top five plans. We have then plotted the agents' home locations, coloured by whether they are alternative bus (green) or rail (orange) plans. This shows us where there is potential to 'nudge' agents onto public transport modes.

The plots show that bus alternatives are concentrated around urban centres, and rail in locations with train stations. We look at how this varies with agent income on the next page. Further analysis of these agents, their plans, and activities would be beneficial when proposing new interventions for specific locations.

We see similar patterns in 2040, which is expected given the lower amount of network changes, but there are now more intense pockets of potential rail users that would be useful to look at in future studies.


2019 Baseline


2040 Baseline

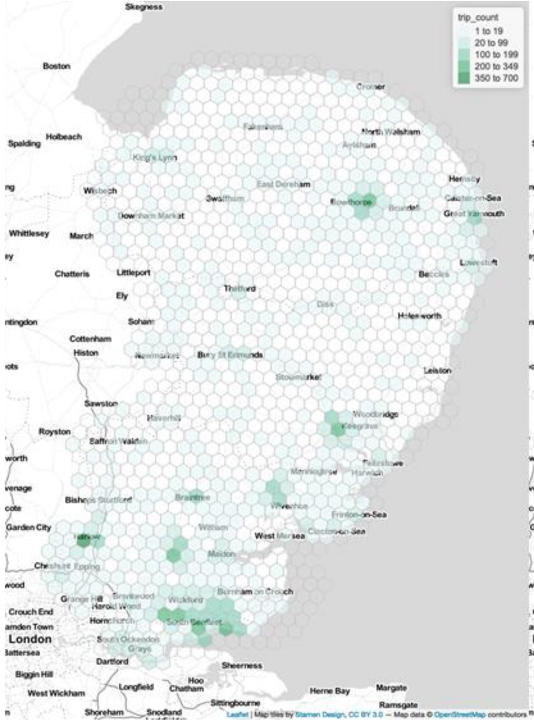
2040 Scenarios: Potential bike plans

Where is the best potential to encourage cycling in the 2040 scenarios?

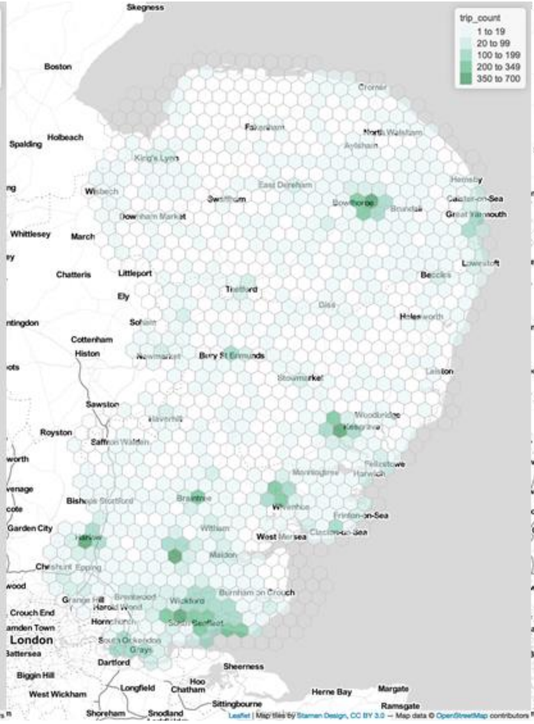
We can aggregate the individual location plots from the previous page to look at a more aggregate view of potential mode shift. Here we look at car trips where the best alternative was to cycle.

We see that bike trips could increase but that the geographic distribution of alternative trips varies between scenarios. In general, trips are concentrated around urban centres and more densely populated areas.

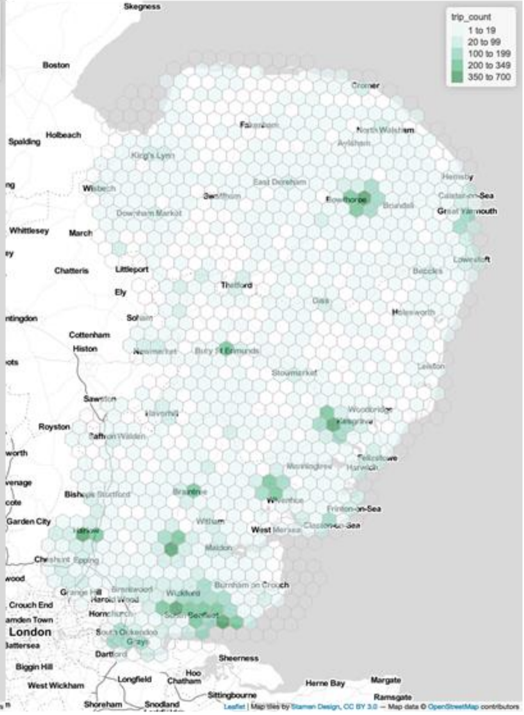
In the active scenario, cycling is an alternative mainly concentrated in urban areas (eg Ipswich). The combined scenario shows a more widespread potential for cycling uptake across both urban and more rural areas (eg Northeast Norfolk).



2040 Baseline



2040 Active



2040 Combined

Agent utility: Insights summary

Agent choice

What is the analysis: We assess an agents choice set to see what insights can be taken from the choices they don't make

Key takeaways:

- This analysis gives us insights into policy driven interventions. The relative disutility of modes where mode shift may be sought can be contextualised and understood at a final spatial level and for different agent types. This overlaps with the equity lens, permitting a better understanding of who, what and where choice is influenced.
- This analysis also gives us insights into resiliency. It highlights how brittle or resilient an agent is to changes. We see that low income agents tend to have less resiliency, as their plan utilities drop off faster compared to high income agents, in both our baseline and future scenarios. We see that in future years this trend tends to expand as the relative differences diverge, to varying degrees. We also see that some of largest interventions (I.e. comprehensive road pricing) stretch the differences between best and worst for different cohorts.

Further work:

- Adding the SEE lens to the equity analyses will give us a more impactful and consequential view on how agent choice is related to distributional impacts. This can be undertaken at various spatial scales.
- Further analysis into the aspects of utility that result in behavioural change. For example, when an agent decides against public transport it may be possible to identify what kind of intervention would be most effective in shaping this behaviour. The agents choice set can inform whether or not a frequency, fare or other policy would be most impactful. Such an analyses would help bridge the gap between policy outcomes and policies, giving us an informed way of generating promising new interventions with a strong evidence base.
- Further development of visualisations and tools, including interactivity.

Scenario insights summary

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Road Pricing scenario summary

Road user charging has the biggest impact on agent behaviour

Key question: What is the impact of increasing per km costs on driving?

Scenarios: Increase of road use costs for all agents by three levels of multiplier; 1.5, 2.5, and 3.

Key observations:

- Road pricing is the most effective measure for reducing the amount that agents travel. This is expected due to the dominance of car within the region.
- All groups of agents suffer a decrease in utility as they try to travel with increased costs, however low income agents are impacted more than those of higher incomes.
- At higher levels of user charging, we see agents move to public transport, in some cases saturating the public transport network, to the detriment of non-car users.
- Freight currently bears the cost increase as no mode shift is possible in the current model.

Insights:

- Road pricing encourages all agents away from driving, however some have no alternative options and have worse outcomes as a result. Many of these are the groups least able to bear increased costs.
- Road pricing without adding public transport capacity is likely to cause issues for non-car users.
- The decarbonisation effect from this mode shift is not significant overall, reflecting the ubiquity of car travel.

Further work:

- Simulation of more complex scenarios involving differential pricing.
- Simulation of more holistic mode shift scenarios, combining road pricing with public transport interventions.
- Allowing for complex freight scenarios (e.g. road to rail).

EV uptake scenario summary

A shift to higher levels of EV ownership contributes most to decarbonisation

Key question: What is the impact of different levels of EV uptake?

Scenarios: Increase EV uptake from 33% in the 2040 baseline to 66% (double), and 88% (DfT Vehicle led Decarbonisation scenario).

Key observations:

- The decrease we see in emissions is very dependent on the fuel efficiency and emissions assumptions for 2040, especially for the remaining combustion vehicle fleet.
- EV uptake reduces emissions across the entire region, including urban areas which would also benefit from an improvement in air quality.
- EV costs are lower in the current assumptions, this leads to an increase in the use of EVs, increasing vehicle km travelled and worsening congestion.
- HGVs emissions are significantly worse in urban areas and on smaller roads as HGVs emit more at lower speeds.
- Our simulation doesn't include EV charging, which may alter journey behaviour for individuals.

Recommendations:

- The cost of using EVs needs to be a key consideration as uptake increases. If the cost of EVs remains lower than for combustion vehicles, it may encourage an increase in driving. Finding ways to mitigate this response should be part of future policy development.
- Encouraging EV uptake needs to be part of any future decarbonisation strategy.
- Especially at the upper limit of our simulations, significant generation of zero carbon electricity and offsetting of emissions will be required to get to a 'Net Zero' network.

Further work:

- Implementing vehicle charging behaviour in the simulation, especially if combined with alternative fuels.
- Improving EV allocation model in response to additional data

Active mode scenario summary

While having a smaller impact overall, active mode improvement will be a key enabler

Key question: What would happen if active modes were twice as appealing?

Scenario: A single simulation with active modes having half the disutility (making them twice as appealing). This looks at the outcome of this change, not how it could be achieved.

Key observations:

- Overall impacts of this scenario on mode shift are small, however, they benefit all different types of agents.
- We see a direct shift to active modes for many journeys, especially shorter distance trips.
- Active modes also benefit public transport modes as they improve access and egress to stations and stops.

Recommendations:

- Active travel should be a priority across all schemes and packages of development as it is an enabler for other non-car modes.
- There is a lot of potential for cycling to be adopted for trips in the 2-5km range.

Further work:

- Dynamic utility for active modes, influenced by factors such as infrastructure type, car interactions, destination facility type etc. This would start to get to the 'how do we achieve this utility increase question?'

Combined scenario summary

Combining all of our scenario interventions doesn't stack their benefits

Key question: If we combine scenarios, how close do we get to net zero?

Scenario: A single simulation containing, high road charging, 88% EV uptake, and the active travel utility boost.

Key observations:

- Our combined scenario reduces carbon emissions by the most across all scenarios. However, it is only marginally more than the high EV scenario.
- We see strong growth in bike and PT modes, almost exclusively at the expense of car (and a very small reduction in walking).
- A lot of the mode shift benefit from the road pricing and active modes is offset by the cheaper EV costs, which encourages more driving.
- Low income agents still experience a reduction in utility in this scenario, but it is of a smaller magnitude than the high road pricing scenario. This will be driven by the combined effect of the specific factors used for road pricing and EV cost.
- Many of the factors we are seeing are the result of the region being very car dependent.

Recommendations:

- When implementing policy and other interventions, care needs to be taken that benefits from one shift aren't negated.
- This kind of multimodal analysis is very valuable in understanding the dynamics between very different factors.

Further work:

- Sensitivity analysis around combinations of EV cost and road pricing factors.
- Additional infrastructure changes to non-car modes to explore more complex modal interactions.

Summary and conclusion

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Executive Summary

What did we do?

Over the last six months, we have achieved a huge amount in building an Agent Based Model (ABM) of the Transport East region. This model was highly ambitious, building on the learning from the Suffolk County ABM, simulating the transport choices of individuals in the region across all modes to produce novel insights into how future behaviours would impact the region and its plan for meeting decarbonisation targets.

We produced two baseline models; one for 2019 and the other a 2040 forecast year. The first of these was benchmarked against a number of different sources and performed very well, especially given the four month build period. The future year model captured some base changes expected in the region by 2040, including demographic shifts, a shift to Electric Vehicles (EVs) and a level of working from home in anticipation of long term post-pandemic behavioural changes.

This forecast showed a region with growing travel demand being placed on a network without comparable growth in capacity. The region's roads became more congested, and more people are taking to public transport compared to 2019 in response to this.

The ABM approach creates a really detailed representation of travel and can be used to look at a number of different angles on transport in the region. This includes looking at different groups of people, different types of journey, how different people respond to changes and shift modes, and fundamentally how they use transport to access opportunities and benefit themselves.

To illustrate this depth of insight, we ran a series of scenarios on top of the 2040 model, looking at how changes in active travel, road pricing, and EV uptake could contribute to achieving a net zero future for the region. Each of our analyses were repeated for each of these outputs and have generated some core findings for the future of transport in the region.

We have worked with stakeholders throughout the process, sharing our process and getting input and feedback on the work to shape the development of the model and its future direction.

Executive Summary

What insights did we generate?

The full report goes into lots of detail on the output of the project, and so for this summary we will highlight some of the key insights that we gained through the simulations that we ran. We run through these insights in the following slides, and full detail is available in the full report.

1. **Equity** should be a key consideration within the region, as older people and those with lower incomes are much less able to adapt to change, especially in rural areas. Impacts are greater for lower income households, and these tend to be negative as we try to change travel behaviour. *One size fits all interventions should be discouraged.*
2. **Road pricing** is most successful at reducing the amount of driving, however in the most extreme cases, this can have a very negative impact on everyone in the region, including those who don't own a car. This stems from a switch to a public transport network that doesn't have sufficient capacity. *Measures to discourage people away from private cars need to be coupled with investment and expansion of alternative modes if it is to be successful.*
3. Even in the most extreme **EV uptake** scenario we looked at, we are only forecasting getting halfway to a 'net zero' future. Measures to encourage EV uptake should be pursued, but priority should be given to strategies to reduce carbon emissions from freight, especially for HGVs. *Non-car emission reduction should be a priority focus for the region.*
4. *Pricing is a key driver of* ***behaviour change for private cars****. If lower costs for Electric Vehicles persist into the future, they are likely to encourage more driving, especially at short distances. While an EV is mostly decarbonised, it is still a vehicle on the road and contributes to congestion.* Discouraging car use for short journeys should be a theme for future development, especially if prices for car use are lower.
5. **Decarbonisation** will be different for different groups of people. Higher income households tend to drive for more trips and tend to drive further, but they are most likely to decarbonise themselves through investment in an EV. Delivering equitable decarbonisation for lower income groups should be a priority.

Executive Summary

What insights did we generate?

6. Improving the appeal of **active modes** increases the number of people using public transport due to an increase in people accessing stations on bike. This is one of the few wholly positive impacts across all groups of people in the model. *Encouraging active modes will have significant whole network impacts.*
7. **Combining interventions** doesn't combine changes or benefits in a linear way. Much of the impact delivered by specific interventions can be cannibalised or undone by others. *A systems view of transport in the region needs to be taken.*

All of these observations are backed up with specific outputs and behaviours seen within the modelling. We are seeing complex second and third order effects within the model that reflect the complexities of individuals' transport choices and are the result of their interactions rather than being baked into the model inputs.

It is worth reiterating that the model is still relatively early in tis development, and has gone well beyond the original 'alpha' aspiration for this scope of work, and is now ready to support a range of different strategic planning and policy questions.

We have shown a range of insights that are useful for Transport East, its local authority partners, and wider stakeholders. At this stage understanding what levers exist that TE can pull or influence, and those that are outside of its control but fundamentally impact its desired outcomes (e.g. levels of working from home) is a valuable exercise.

It would be possible to generate even more insights from the outputs of the generated scenarios, as the scale of the analysis that is available is potentially overwhelming. Therefore we recommend that methods of sharing the output of the modelling with a wider group of organisations and stakeholders are developed. This will maximise the value that the modelling will provide to the region and open up the modelling for more detailed scrutiny. This will be key for building confidence in the approach within the industry and understanding what this modelling approach is best used for more generally.

Executive Summary

What is the future for the model?

The different components on the Transport East model have all been through a number of iterations during this project, and we expect them all to have further iteration and refinement as the model is used to answer specific questions. The way the model is architected means that these individual improvements can all feed back into the core model. Indeed, a number of potential new scenarios have been identified as part of this project.

It is worth noting the scale of the development that has been possible within a short four month period. Developing a model and getting this much insight from it in four months shows that data driven analysis is feasible at a strategic level. Future studies and scenarios will potentially be able to be turned around in as little as a month now the base model has been developed.

This kind of incremental development will help keep the model current and up to date without the need for large refresh projects. Smaller pieces of work to add in new base datasets or define new outputs can be undertaken as standalone activities if needed.

We have had good engagement from both local and national stakeholders, especially the Department for Transport, National Highways, and Network Rail. Understanding how the model can become part of a consistent evidence base to support both local and national studies will prove valuable going forward.

Finally, there are a range of opportunities to continue the engagement that has begun with the 'monthly demos' stakeholder group. This has been one of the more unexpected outcomes of the project, creating a group of interested and engaged individuals from a wide range of organisation. While continuing in-person engagement may be require a lot of resources, finding a way to continue supporting and engaging with the group is likely to be valuable.

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Appendix

Appendix Contents

Additional material in support of the report

- **Scenario configuration descriptions**
- Scheme list for 2040 network
- Mode shift plots for additional scenarios

2019 Baseline

Scenario Specification

Purpose
Establish and validate a baseline scenario

Population Input
- 2019 population extrapolated from census 2011, controlled against ONS and NTEM datasets
- Activity plans sampled from NTS

Network Input
- 2019 network
- Full road detail in study area, with 10km mid-detail buffer
- Full GB strategic network

Freight
- The majority of parameters are based on the RTM and OSM datasets
- We made simplified assumptions to simulate stops and dwell time

Vehicle Fleet
- As-is represented from latest NTS

Road Pricing
- None

Notes

2040 Baseline

Scenario Specification

Purpose
Establish a "Do Minimum" scenario for 2040, including forecasts for population, EVs and infrastructure change

Population Input
- New population generated from 2040 forecasts.
- Plans sampled from existing NTS
- WFH rate applied to office based workers (relocation of work activity) based on NTS categories

Network Input
- 2019 Baseline network with confirmed new link road schemes
- Simplified Elizabeth Line (Heathrow - Liverpool Street - Shenfield)

Freight
- Forecast using the National Road Traffic Forecast

Vehicle Fleet
- Electric Vehicles distributed across population (flat EV level from TAG data book)
- Combustion fleet (car and freight) emissions estimates aligned to TAG assumptions for 2040

Road Pricing
- None

Notes
- New links represented are detailed in attached future networks note
- Junction upgrades don't impact our network so have been excluded
- Vehicle fleet changes based on TAG assumptions
- NTS employment categories are used to create a WFH population. Categories to have WFH applied:
  - Managerial and technical occupations
  - Skilled occupations - non-manual
  - Professional

2040 – Road Pricing Scenarios

Scenario Specification

Purpose
What is the impact of increasing per km costs on driving? Low/medium/high scenarios

Population Input
- New population generated from 2040 forecasts.
- Plans sampled from existing NTS
- WFH rate applied to office based workers (relocation of work activity) based on NTS categories

Network Input
- 2019 Baseline network with confirmed new link road schemes
- Simplified Elizabeth Line (Heathrow - Liverpool Street - Shenfield)

Freight
- Forecast using the National Road Traffic Forecast

Vehicle Fleet
- Electric Vehicles distributed across population (flat EV level from TAG data book)
- Combustion fleet (car and freight) emissions estimates aligned to TAG assumptions for 2040

Road Pricing
- 3 levels of charging: 1.5x, 2x, and 3x base car cost per mile
- Car, LGV, and HGV will all pay

Notes
- Base as per 2040 Baseline

2040 – EV Uptake Scenarios

Scenario Specification

Purpose
What is the impact of different future EV uptake scenarios (high and very high above the base forecast)

Population Input
- New population generated from 2040 forecasts
- Plans sampled from existing NTS
- WFH rate applied to office based workers (relocation of work activity) based on NTS categories

Network Input
- 2019 Baseline network with confirmed new link road schemes
- Simplified Elizabeth Line (Heathrow - Liverpool Street - Shenfield)

Freight
- Forecast using the National Road Traffic Forecast

Vehicle Fleet
- Electric Vehicles distributed across population
- Two levels of increased EV – double the baseline from TAG and the DfT vehicle led decarb scenario (car and LGV).
- Combustion fleet (car and freight) emissions estimates aligned to TAG assumptions for 2040

Road Pricing
- None

Notes
- Base as per 2040 Baseline

2040 – Active Travel

Scenario Specification

Purpose
What is the impact of increased active mode use from behaviour change and improvements to active infrastructure?

Population Input
- New population generated from 2040 forecasts.
- Plans sampled from existing NTS
- WFH rate applied to office based workers (relocation of work activity) based on NTS categories

Network Input
- 2019 Baseline network with confirmed new link road schemes
- Simplified Elizabeth Line (Heathrow - Liverpool Street - Shenfield)

Freight
- Forecast using the National Road Traffic Forecast

Vehicle Fleet
- Electric Vehicles distributed across population (flat EV level from TAG data book)
- Combustion fleet (car and freight) emissions estimates aligned to TAG assumptions for 2040

Road Pricing
- No charging

Notes
- Base as per 2040 Do Minimum
- Half disutility for cycle / walking to represent better walking and cycling facilities
- Remove fixed cost for cycling
- Quantify as a change to value of time

2040 – Combined Scenario

Scenario Specification

Purpose
If we combine all the other scenarios, how close do we get to net zero?

Population Input
- New population generated from 2040 forecasts.
- Plans sampled from existing NTS
- WFH rate applied to office based workers (relocation of work activity) based on NTS categories

Network Input
- 2019 Baseline network with confirmed new link road schemes
- Simplified Elizabeth Line (Heathrow - Liverpool Street - Shenfield)

Freight
- Forecast using the National Road Traffic Forecast.
- This provides estimates relative to 2015, therefore the forecast was adjusted to 2019 data

Vehicle Fleet
- Electric Vehicles distributed across population (flat EV level from TAG data book)
- Combustion fleet (car and freight) emissions estimates aligned to TAG assumptions for 2040

Road Pricing
- Road User / Fuel Pricing
- Urban Zone Charging

Notes
- Combination of all the previous 2040 scenarios "high" cases. High charging, Very high EV uptake and active mode improvements
- Otherwise as per 2040 baseline

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Schemes included in future network

Scheme	Stage	Source
Gull Wing, bridge for Lowestoft	2023 completion	https://www.suffolk.gov.uk/roads-and-transport/transport-planning/gull-wing-lowestoft/
A12 proposed new dual carriageway at Woodbridge	2025 completion	https://www.suffolk.gov.uk/council-and-democracy/consultations-petitions-and-elections/consultations/a12-improvements/#junctionbyjunction
Great Yarmouth Third River Crossing	2023 completion	https://www.norfolk.gov.uk/roads-and-transport/major-projects-and-improvement-plans/great-yarmouth/third-river-crossing
Norwich Western Link	2023 start	https://www.norfolk.gov.uk/roads-and-transport/major-projects-and-improvement-plans/norwich/norwich-western-link
Long Stratton Bypass	2025 completion	https://www.norfolk.gov.uk/roads-and-transport/major-projects-and-improvement-plans/countywide/long-stratton-bypass
A120 to A133 Link Road: dual-carriageway between the A120 and A133	2024 completion	https://www.essexhighways.org/a120-a133-link-and-rapid-transit
A127/A130 Fairglen Interchange: new 'Southend Link Road'	2022 start	https://www.essexhighways.org/a127-a130-fairglen-interchange
Chelmsford North East Bypass	2024 completion	https://www.essexhighways.org/chelmsford-north-east-bypass

Schemes not included in future network

Scheme	Stage	Source	Reason for not including
A14 Junction 55 Copdock Interchange	Consultation completed	https://nationalhighways.co.uk/our-roads/pipeline-of-possible-future-schemes/a14-junction-55-copdock-interchange/	do not inlcude junction improvements; no timeline announced
A47 North Tuddenham to Easton improvement	Approved, 2025 completion	https://nationalhighways.co.uk/our-roads/east/a47-north-tuddenham-to-easton-improvement/#documents	only approved 12th August
A47 - A11 Thickthorn Junction	Awaiting decision	https://infrastructure.planninginspectorate.gov.uk/projects/eastern/a47-a11-thickthorn-junction/#	not clear if going forward
A47 Great Yarmouth junctions improvements	Consultation completed	https://nationalhighways.co.uk/our-roads/east/a47-great-yarmouth-junctions-improvements/	not clear if going forward
A47 Guyhirn junction	2023 completion	https://nationalhighways.co.uk/our-roads/east/a47-guyhirn-junction/	do not include junction improvements
Braintree Integrated Transport Package (ITP)	Consultation completed	https://www.essexhighways.org/braintree-itp	do not include junction improvements; not modelling pedestrian movement;
Broomfield Hospital NHS Roundabout improvements	In progress	https://www.essexhighways.org/broomfield-hospital-nhs-roundabout	do not include roundabout improvements
West Winch Housing Access Road (WWHAR)	Feasibility work underway	https://www.norfolk.gov.uk/roads-and-transport/major-projects-and-improvement-plans/kings-lynn/west-winch-housing-access-road	timeline unclear
A148 Fakenham Roundabout Enhancement	Feasibility work underway	https://norfolkcc.maps.arcgis.com/apps/MapJournal/index.html?appid=0889b37866b0432ca12bddb6afb30f3d	do not include roundabout improvements
A17/A47 Pullover Junction	Feasibility work underway	https://norfolkcc.maps.arcgis.com/apps/MapJournal/index.html?appid=0889b37866b0432ca12bddb6afb30f3d	do not include junction improvements
M11 Junction 8 Improvements	In progress	https://www.essexhighways.org/m11-junction-8-improvement-scheme	do not include junction improvements
East-West rail	In progress	https://eastwestrail.co.uk/the-project/project-overview	would require a separate scenario

Schemes not included in future network

Scheme	Stage	Source	Reason for not including
Defoe Road and Henley Road Pedestrian and off-road cycle provision	Consultation completed	https://www.suffolk.gov.uk/council-and-democracy/consultations-petitions-and-elections/consultations/defoe-road-and-henley-road-pedestrian-and-off-road-cycle-provision/	not modelling pedestrian movement; not clear if going forward
Improvements of walking and cycling provision on Melford Road	Consultation completed	https://www.suffolk.gov.uk/coronavirus-covid-19/advice-on-travel/active-travel-improvements-for-cycling-and-walking/melford-road-sudbury/	not modelling pedestrian movement; not clear if going forward
Proposed 30mph speed limit for the Parish of Oulton	Consultation completed	https://www.suffolk.gov.uk/council-and-democracy/consultations-petitions-and-elections/consultations/proposed-30mph-speed-limit-for-parish-of-oulton-hall-lane-wood-lane-and-holly-hill-order-202/	not clear if going forward
Proposed 40mph speed limit – Various roads in the parishes in and adjacent to Oulton Division	Consultation completed	https://www.suffolk.gov.uk/council-and-democracy/consultations-petitions-and-elections/consultations/proposed-40mph-speed-limit-numerous-roads-in-the-parishes-in-and-adjacent-to-oulton-division/	not clear if going forward
A1(M) junction 6 to junction 8 smart motorway	Work paused to focus on other projects	https://nationalhighways.co.uk/our-roads/east/a1-m-junction-6-to-junction-8-smart-motorway/	not clear if going forward
A120 Braintree to A12	Pipeline project	https://nationalhighways.co.uk/our-roads/east/a120-braintree-to-a12/	not clear if going forward
A120 Millennium Way Slip Roads	Planning application submitted	https://www.essexhighways.org/highway-schemes-and-developments/highway-schemes/braintree-schemes/a120-millennium-way	do not include slip roads
Boreham Capacity Improvements	In progress	https://www.borehamcapacityimprovements.co.uk/background/	do not include roundabout improvements
St Botolph's Circus Roundabout	Timeline unclear	https://www.essexhighways.org/st-botolphs-circus	do not include roundabout improvements
A127 Economic Growth Corridor	Timeline unclear	https://essexhighways.org/highway-schemes-and-developments/major-schemes/a127-economic-growth-corridor?_gl=1*17ri6y0*_ga*MTYyNTcwMTg0Ni4xNjYwNjY1MDQ5*_ga_YZH6J70T6X*MTY2MDcyODQ3MC4zLjEuMTY2MDcyODYwMC4wLjAuMA..	not clear if going forward

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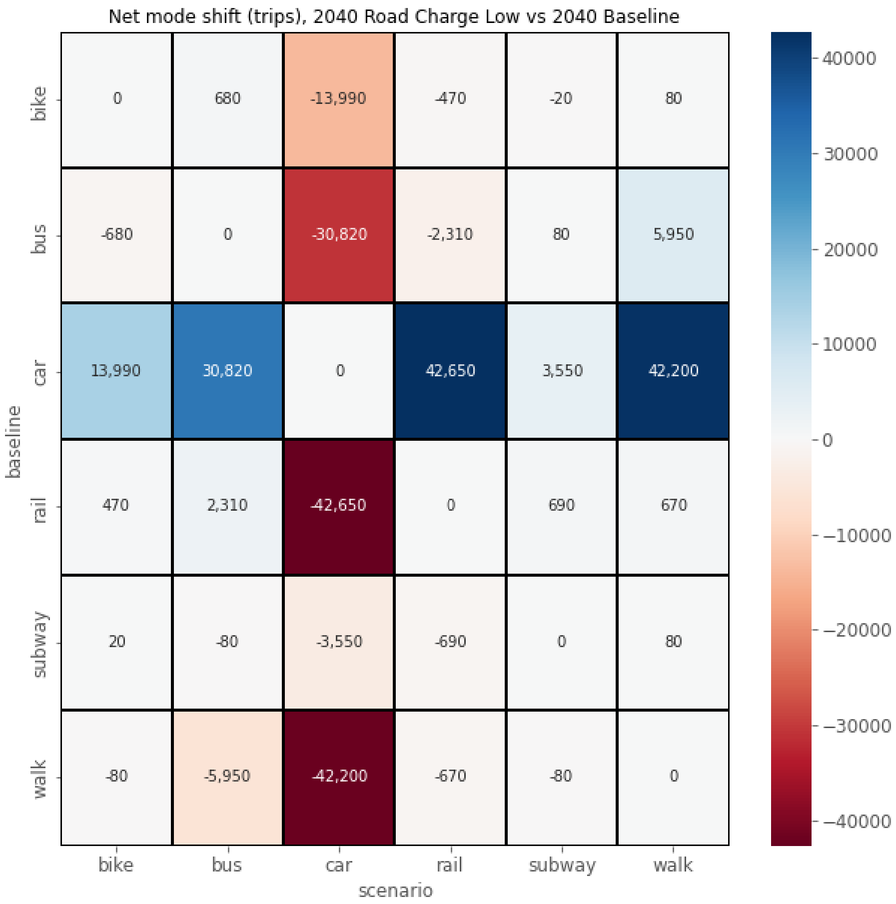
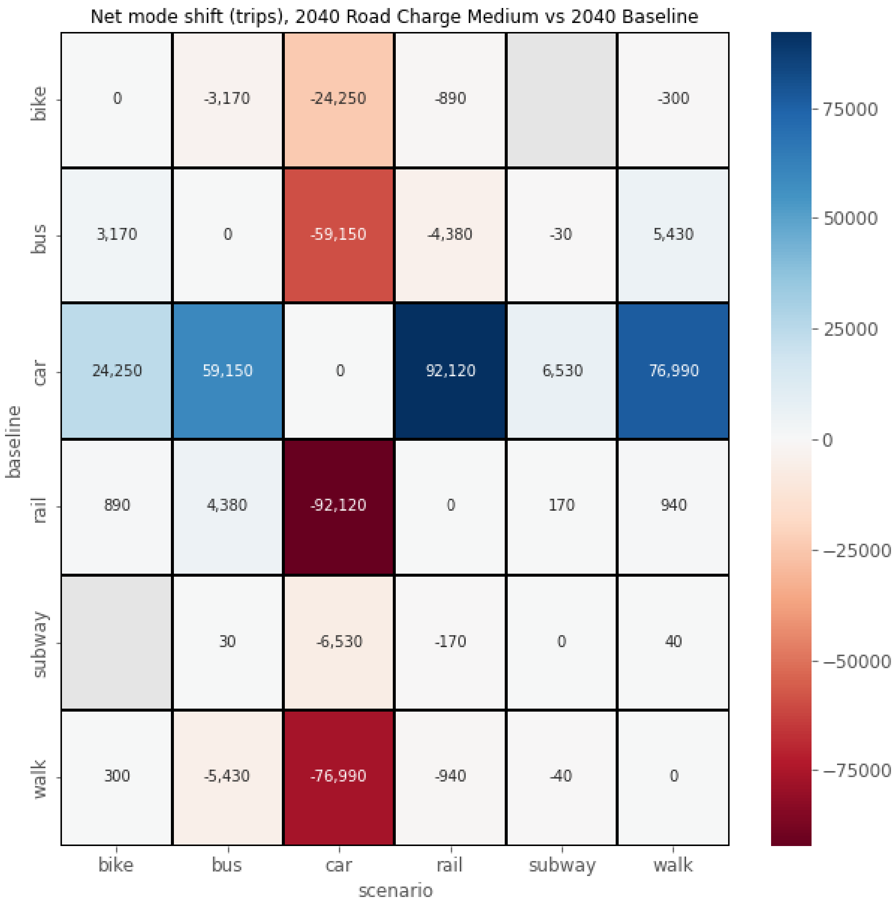
Mode shifts

Low and medium charging scenarios





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